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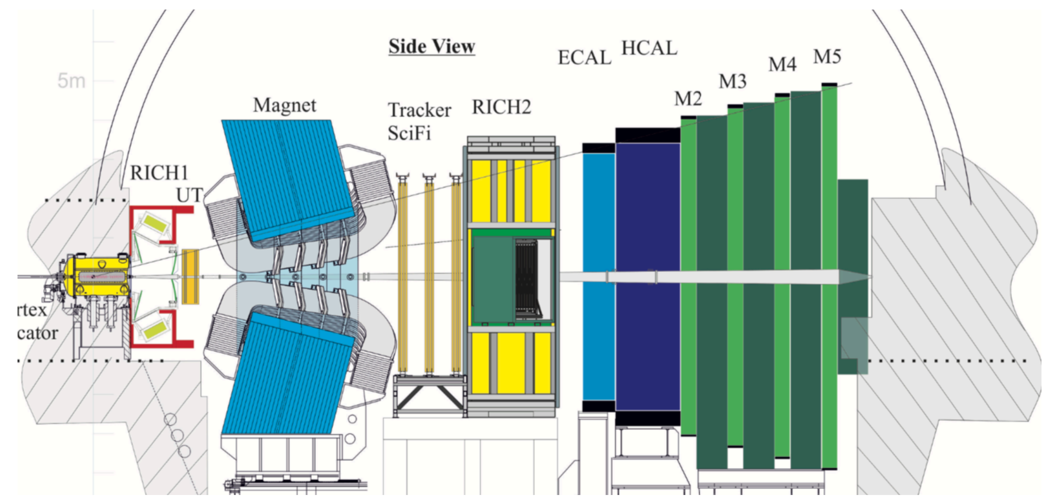
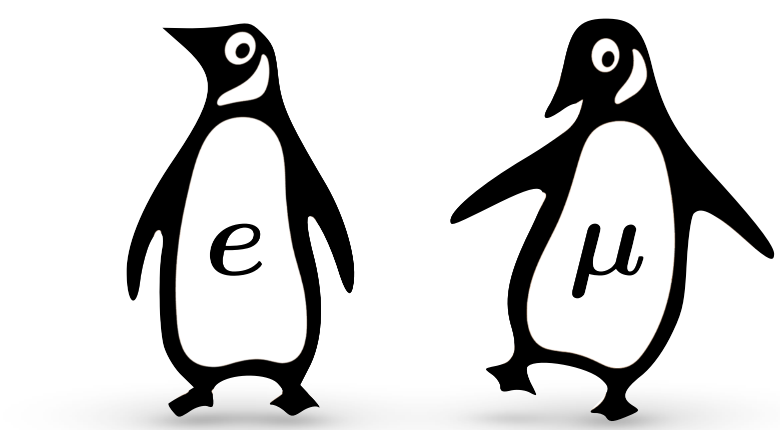
Anomalies in rare b decays - a review

Martino Borsato
on behalf of the LHCb collaboration
Universität Heidelberg
martino.borsato@cern.ch
@MartinoBorsato

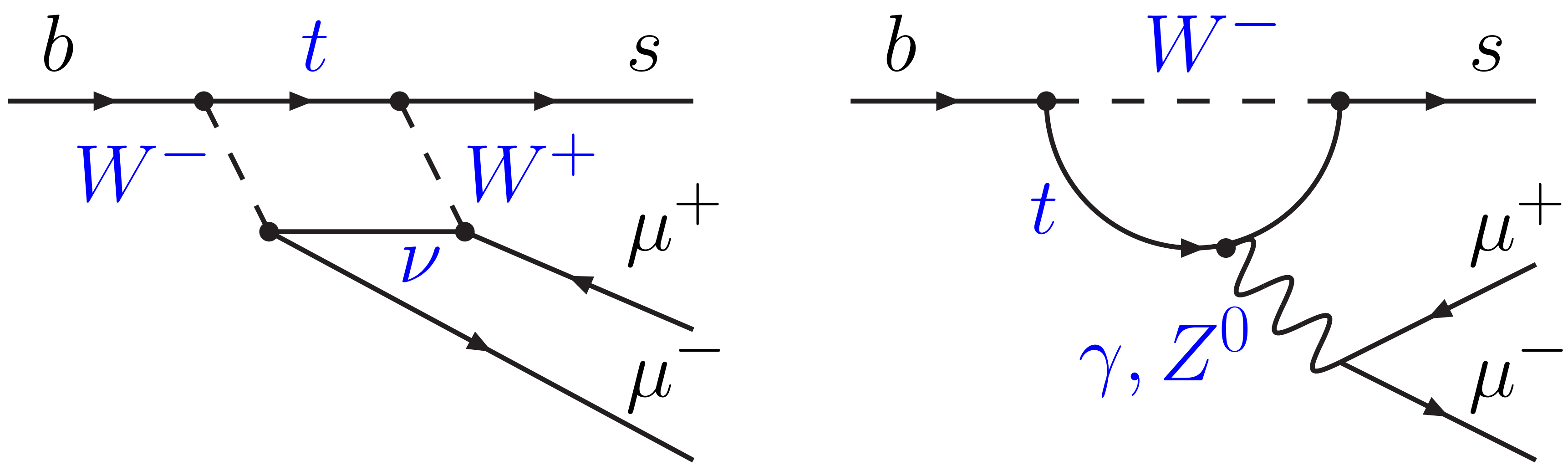
Outline

- Rare B decays to search for NP
  - Effective approach
  - Energy scale
- $b \to s\mu\mu$ at LHCb
  - $b \to s\mu\mu$ and $B_s \to \mu^+\mu^-$ branching ratios
  - $B^0 \to K^*\mu^+\mu^-$ angular analysis
- Lepton Universality tests
  - Electrons vs muons at LHCb
  - Experimental results (R_K, R_{K*}, R_{pK})
- Prospects
  - $B^0 \to K^*e^+e^-$ angular analysis
  - With Run 2 data on tape
  - With upcoming upgrade



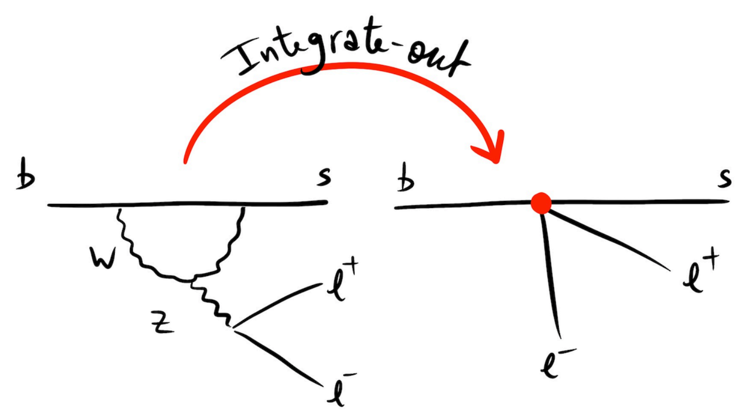


$b \to s\ell\ell$ transitions



- $b \to s\ell^+\ell^-$ is a golden channel
  - Flavour-changing $b \to s$ neutral current
  - Forbidden at tree-level in SM → BR of $10^{-6} - 10^{-10}$
  - New physics contribution can be same order as SM

Energy scale



Effective-Hamiltonian approach

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\frac{e^2}{16\pi^2}V_{tb}V_{ts}^*\sum_i C_i O_i + \text{h.c.}$$

NP enters here $C_i = C_i^{\text{SM}} + C_i^{\text{NP}}$

Operator encoding Lorentz structure

- $b \to s\ell\ell$ is loop and CKM suppressed in the SM
- New physics may share these features or not → different energy reach

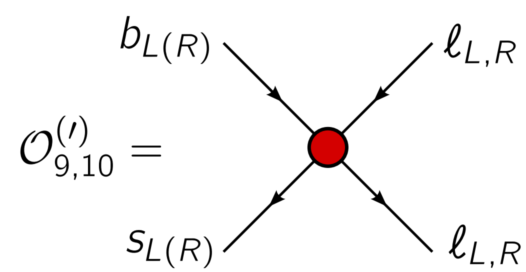
$$\Lambda_{\text{NP}} \times \sqrt{|\mathcal{C}_{9,10}^{\text{NP}}|} \sim \begin{cases} \frac{4\pi\sqrt{2}M_W}{ge\sqrt{|V_{tb}V_{ts}^*|}} = 36\,\text{TeV} & \text{(generic tree level)}, \\ \frac{\sqrt{2}M_W}{e\sqrt{|V_{tb}V_{ts}^*|}} = 2\,\text{TeV} & \text{(weak loop)}, \\ \sqrt{2}M_W/e = 400\,\text{GeV} & \text{(MFV, weak loop)}. \end{cases}$$

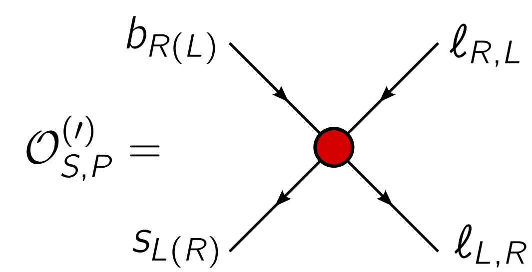
→ more on the interpretation of $b \to s\ell\ell$ in Aritra Biswas talk

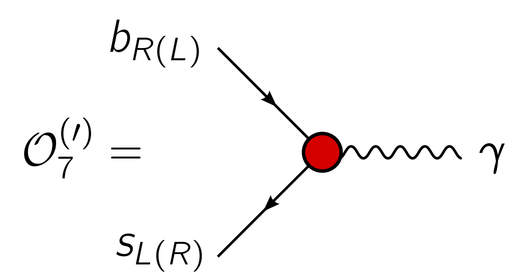
$b \to s\ell\ell$ transitions

courtesy of D.Straub

$$\mathscr{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\frac{e^2}{16\pi^2}V_{tb}V_{ts}^* \sum_i C_i O_i + \text{h.c.}$$



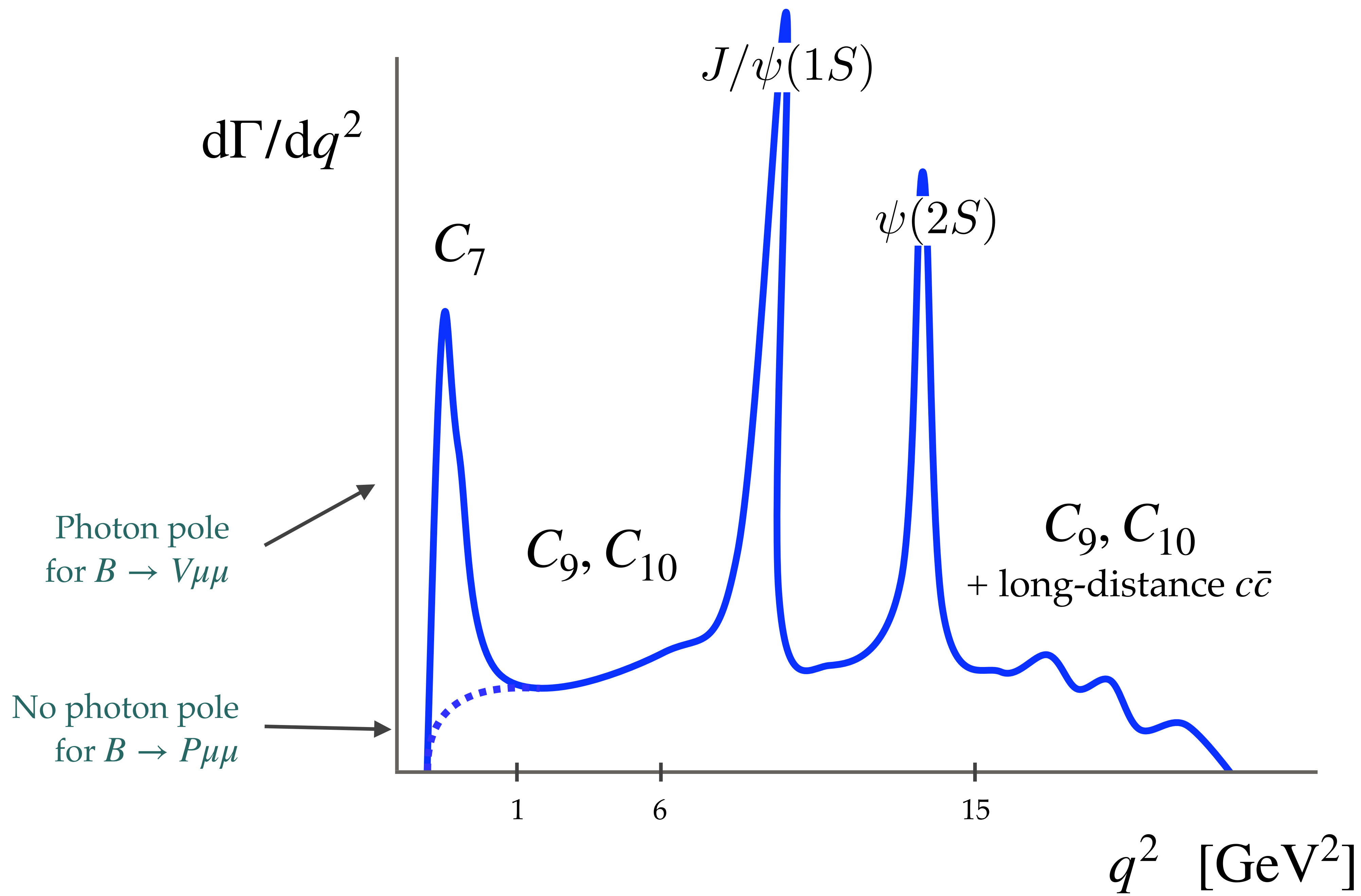




- Relevant dimension-6 operators:
  - Four-quark operators (entering through hadronic effects)
  - Dipole operators $C_7^{(\prime)}$ (constrained by radiative decays)
  - Semi-leptonic operators $C_9^{(\prime)}$, $C_{10}^{(\prime)}$ $\to$ main interest for NP searches

Decay	$C_7^{(\prime)}$	$C_9^{(\prime)}$	$C_{10}^{(\prime)}$	$C_{S,P}^{(\prime)}$
$B \to X_s\gamma$	X			
$B \to K^*\gamma$	X			
$B \to X_s\ell^+\ell^-$	X	X	X	
$B \to K^{(*)}\ell^+\ell^-$	X	X	X	
$B_s \to \mu^+\mu^-$			X	X

q^2 spectrum

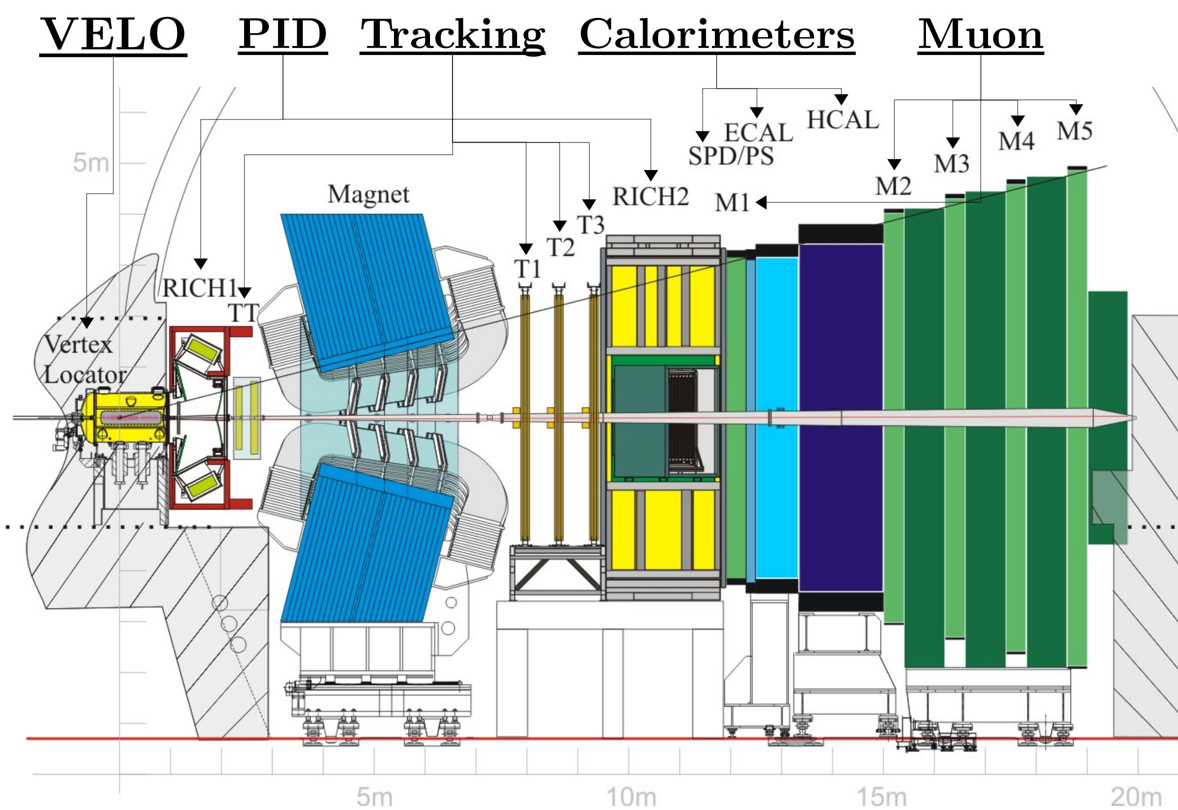

$J/\psi(1S)$
$\mathrm{d}\Gamma/\mathrm{d}q^2$
$\psi(2S)$
C_7
Photon pole
for $B \to V\mu\mu$
C_9, C_{10}
C_9, C_{10}
+ long-distance $c\bar{c}$
No photon pole
for $B \to P\mu\mu$
1
6
15
q^2 [GeV^2]

The LHCb experiment

The LHCb experiment

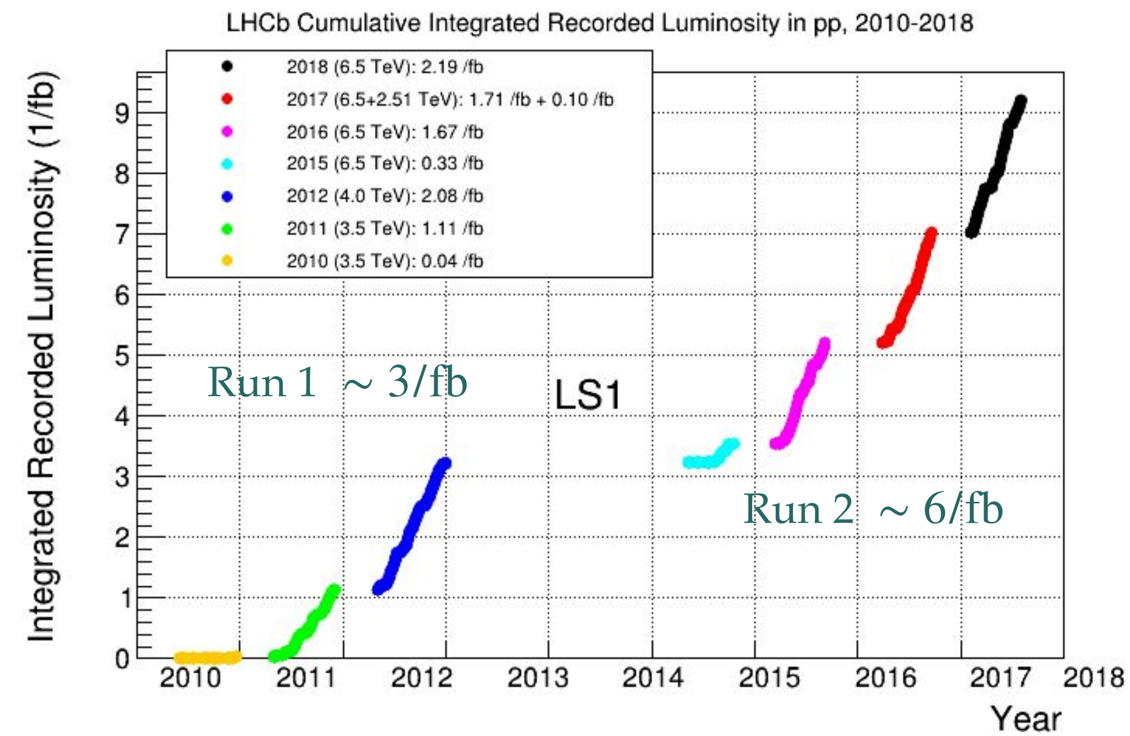
Int.J.Mod.Phys. A 30, 1530022 (2015)

- **LHC pp collisions at 7-13 TeV**
  - Huge $pp \to b\bar{b}X$ cross-section of order mb
  - Large background $\sigma(\text{inelastic}) \simeq 200\sigma(b\bar{b})$
- **LHCb optimised to select b-hadrons**
  - In the forward region of pp collisions
    - Where most of $b\bar{b}$ are produced
  - Low-p_T triggers with calo and muon-ch.
    - Running at lower luminosity w.r.t. ATLAS/CMS
  - Identify displaced b-hadron vertex
    - Leveraging large boost in forward region
  - Precise momenta with spectrometer
    - Separate partially reconstructed b-hadron decays

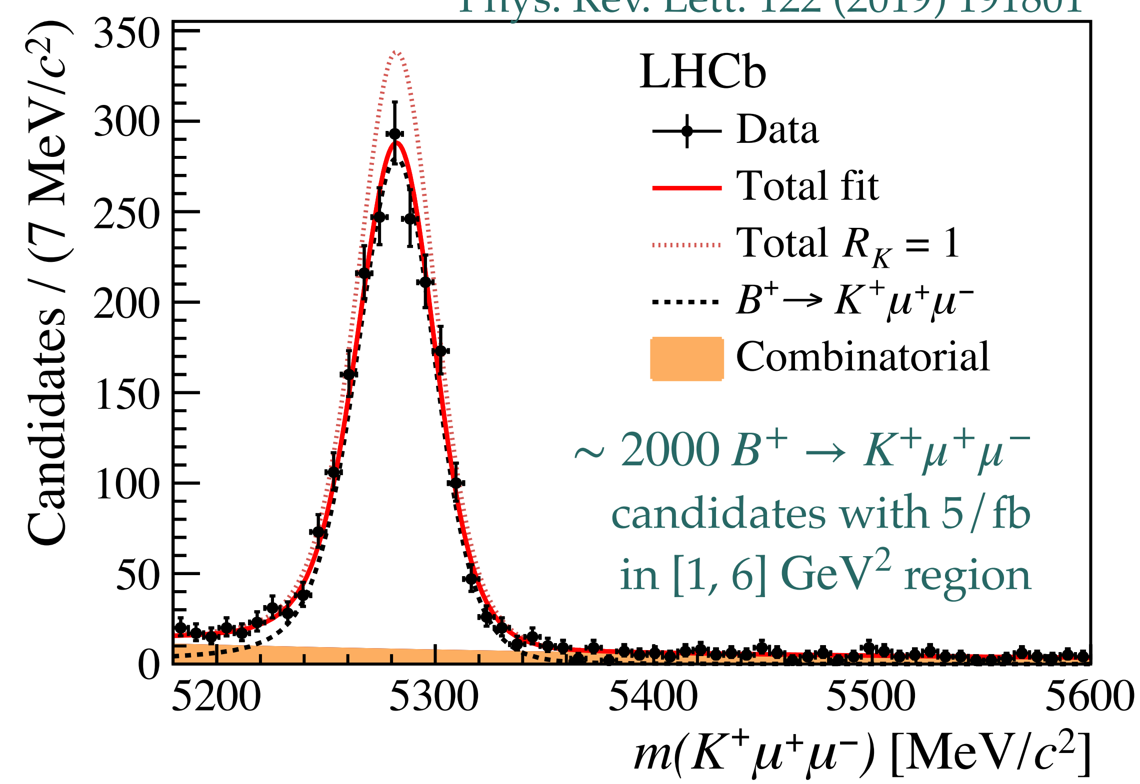


The LHCb experiment

- **Excellent performance in LHC Run 1 and 2**
  - About 10^{12} $b\bar{b}$ in the acceptance
  - Recorded world-largest sample of $b \to s\mu\mu$ decays



Phys. Rev. Lett. 122 (2019) 191801

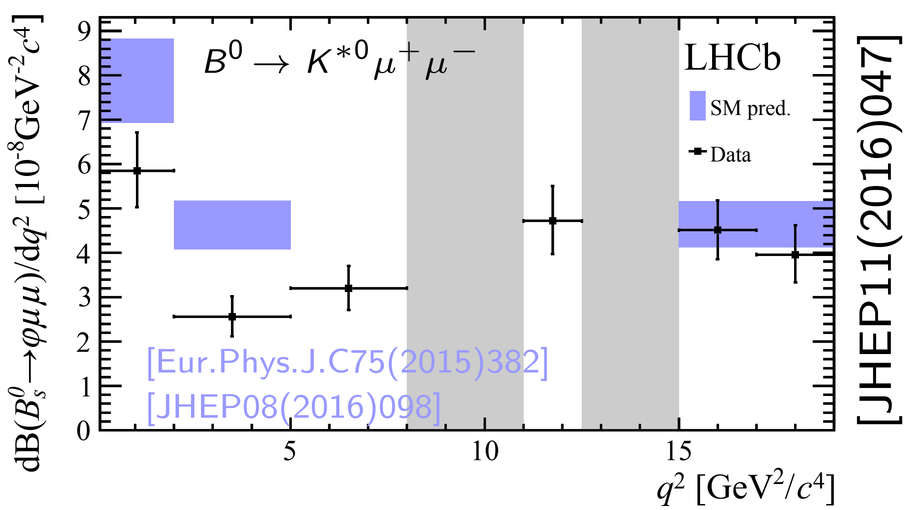


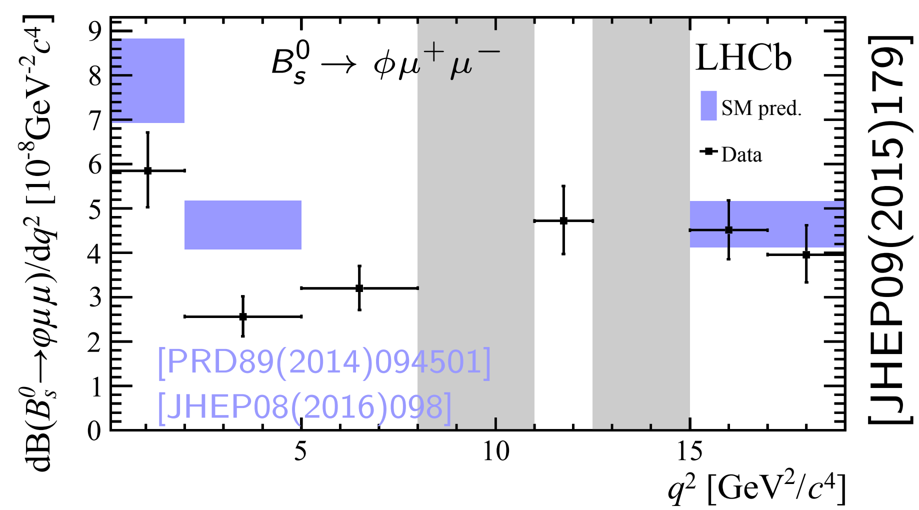
Anomalies in $b \to s\mu\mu$

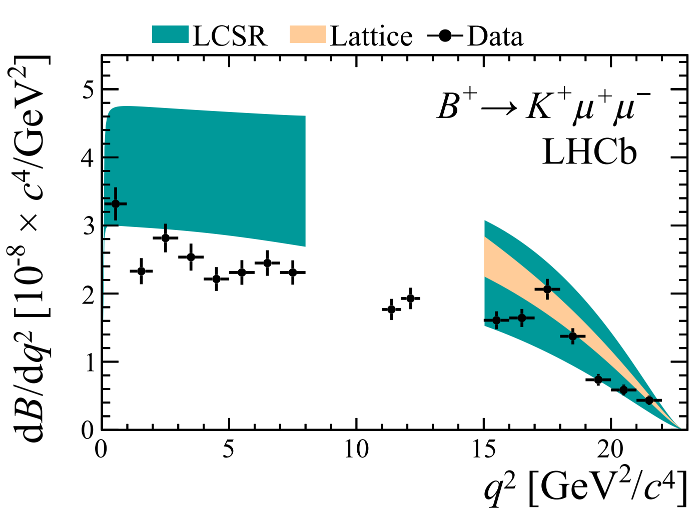
Branching ratio measurements

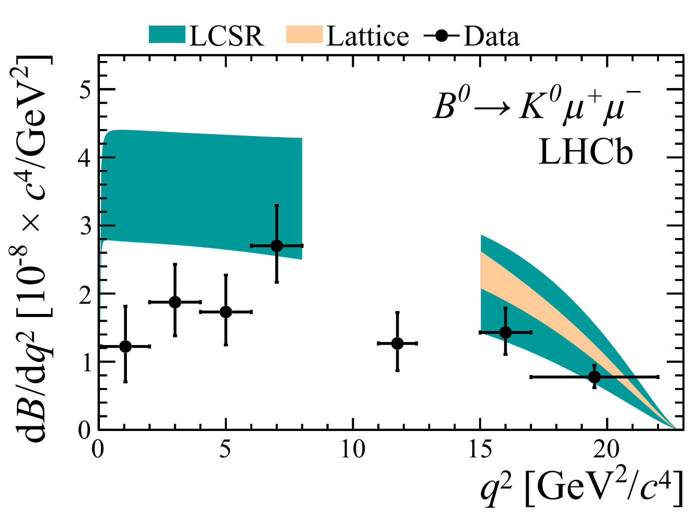
dB/dq^2 in exclusive $b \rightarrow s\mu\mu$ seems *to* undershoot SM predictions

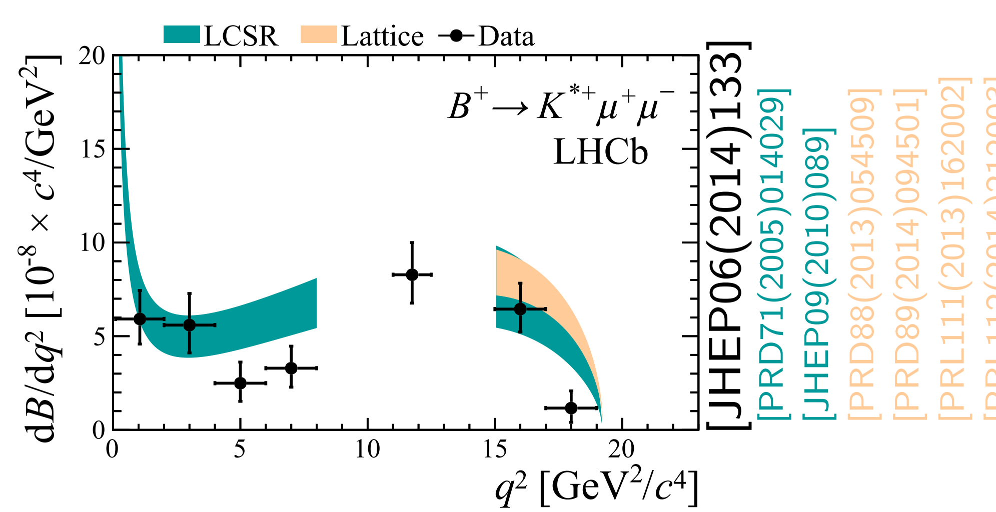
- Theory uncertainties ~20-30% (hadronic form factors)
- Pattern is coherent, but predictions uncertainties are correlated
- Inclusive $B \rightarrow X_s\mu\mu$ measurement very hard at LHCb



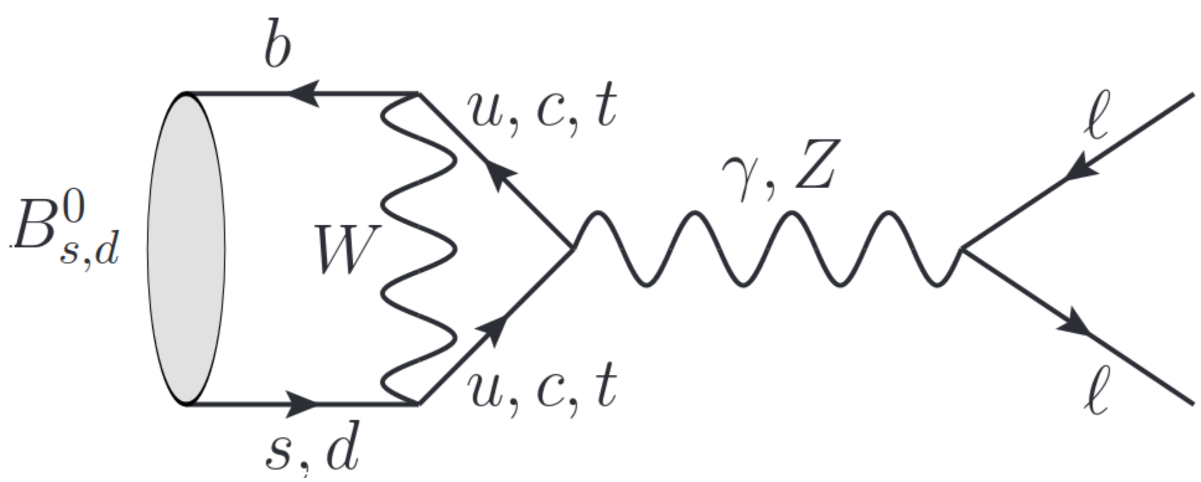






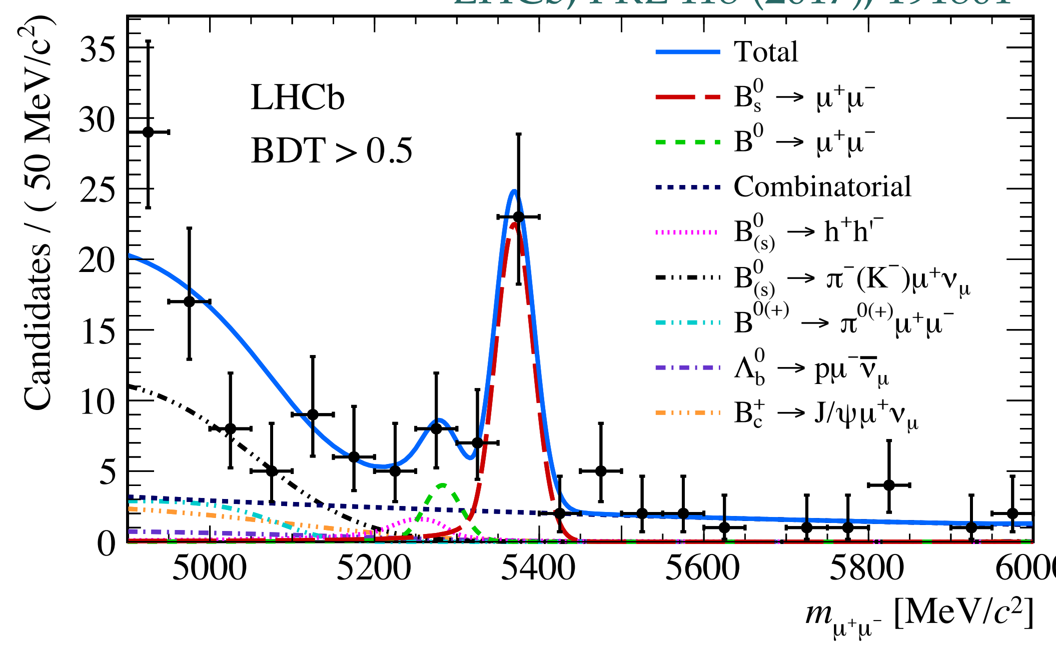


$B_{(s)} \to \mu^+\mu^-$



+ box diagram with neutrinos

LHCb, PRL 118 (2017), 191801



- Purely leptonic $B_{(s)} \to \mu^+\mu^-$ decay
  - Same diagrams as $b \to s\mu\mu$ (rotated)
  - Much smaller BR because of helicity suppression
  - More precise predictions because of $\mu\mu$ final state
  - Theoretically clean probe of C_{10} Wilson coefficient
    - Will be a key player to understand the anomalies in the near future

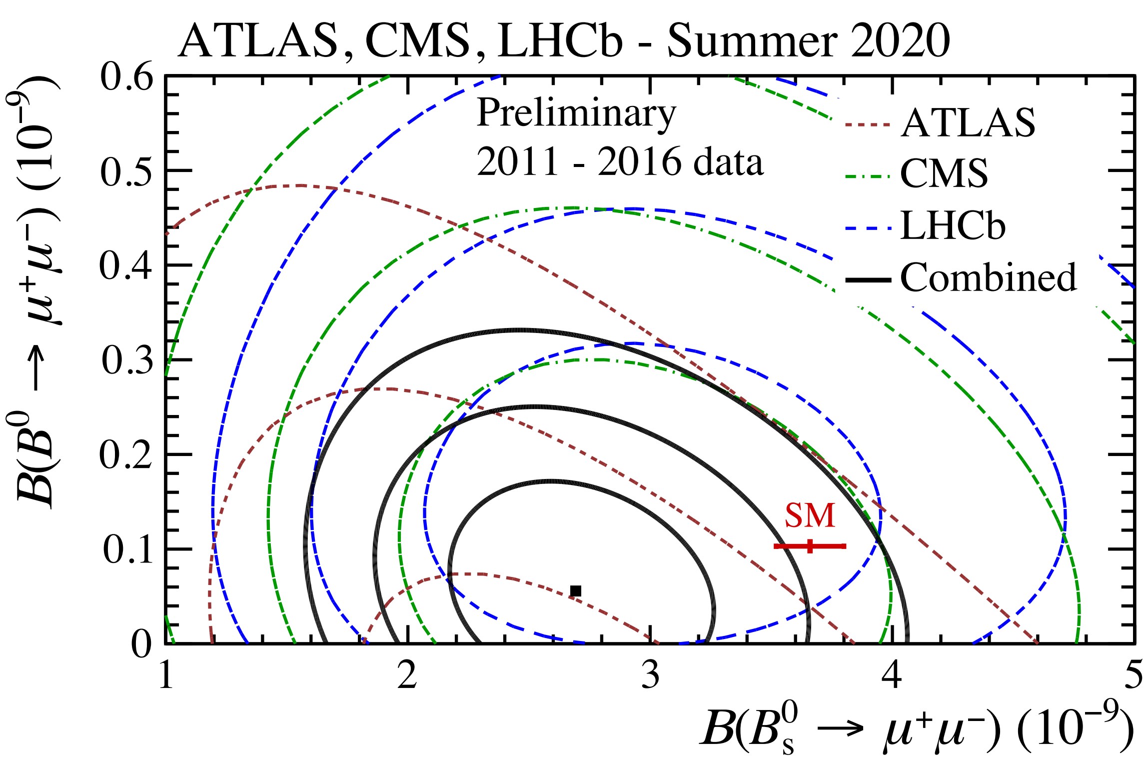
$B_{(s)} \to \mu^+\mu^-$ LHC combination

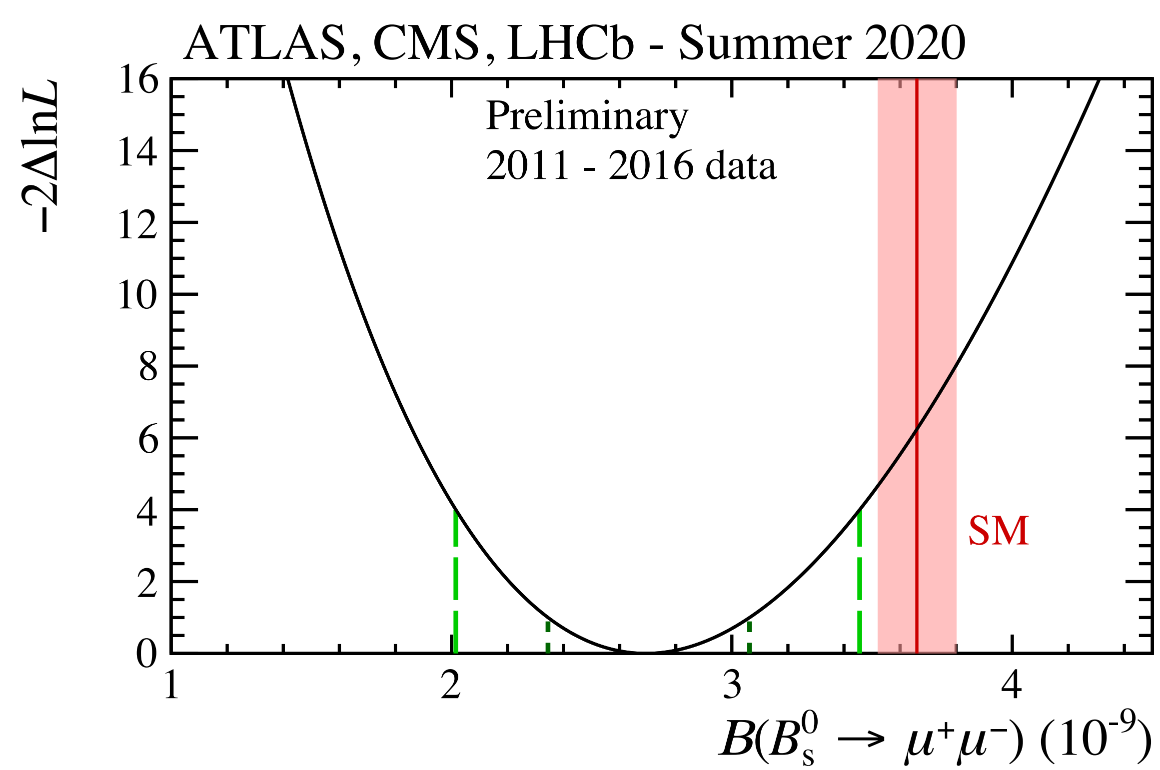
LHCb-CONF-2020-002

- Latest BR predictions have precision at 4-5% level:
  $\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\right) = \left(3.66 \pm 0.14\right) \times 10^{-9}$
  $\mathcal{B}\left(B^0 \to \mu^+\mu^-\right) = \left(1.03 \pm 0.05\right) \times 10^{-10}$
  Beneke et al JHEP 10 (2019) 232

- ATLAS+CMS+LHCb combination:
  $\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\right) = \left(2.69^{+0.37}_{-0.35}\right) \times 10^{-9}$
  $\mathcal{B}\left(B^0 \to \mu^+\mu^-\right) < 1.9 \times 10^{-10}$ at 95% CL

2.1σ deviation compatible with other anomalies

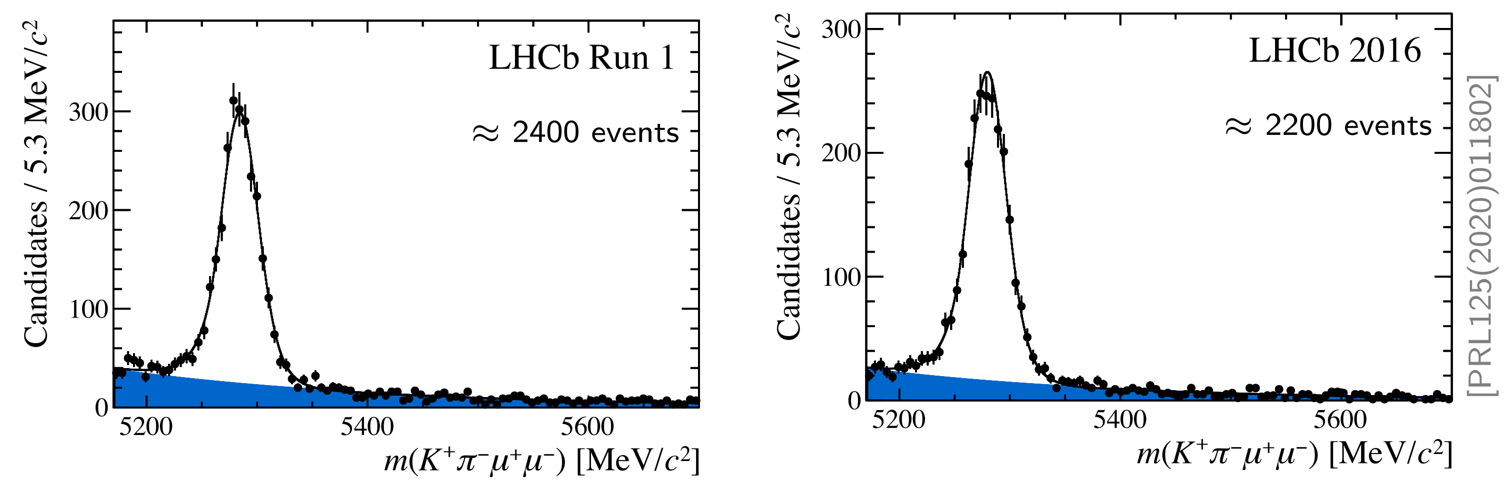




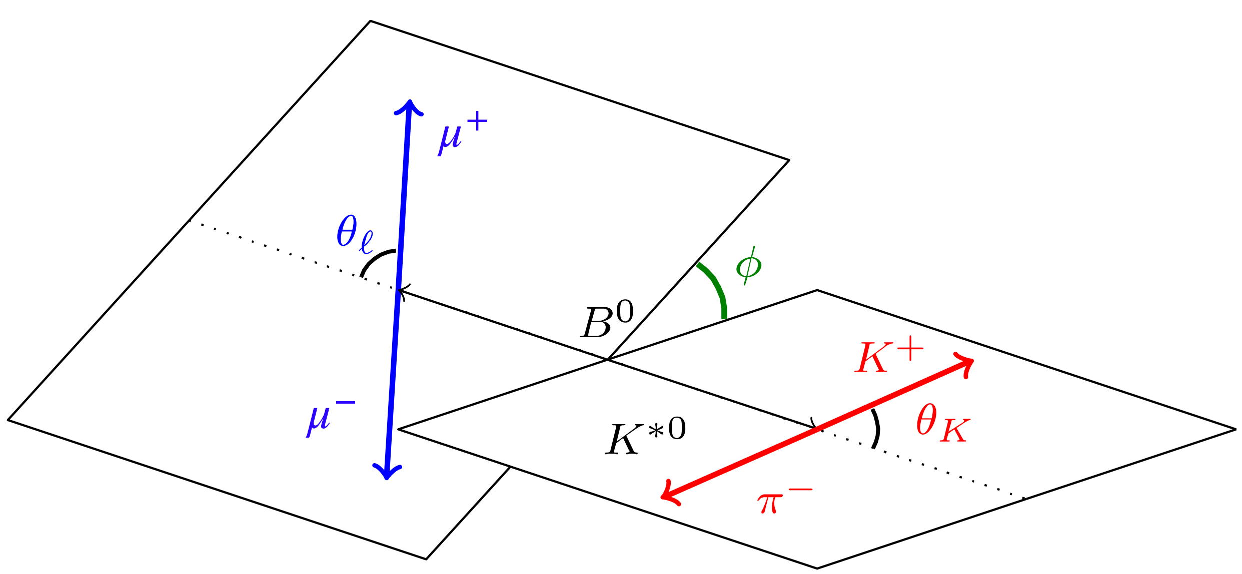
$B^0 \to K^*\mu^+\mu^-$ angular analysis

PRL 125(2020)01 1802

- $B^0 \to K^*(K^+\pi^-)\mu^+\mu^-$ gives 4-particle final state with rich structure
- Angular analysis in fine bins of q^2 performed with 6/fb (~4600 signal candidates)
- Kinematics defined by 3 angles
  - Complicated description



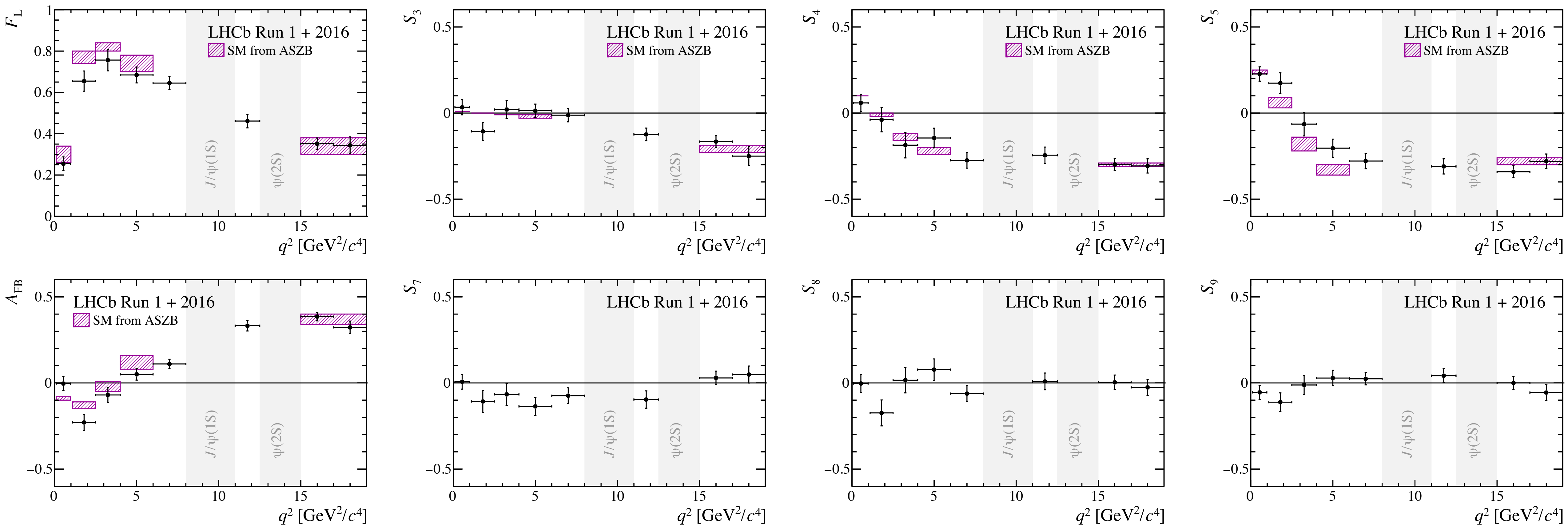
$$\frac{1}{d(\Gamma+\bar{\Gamma})/dq^2}\frac{d^4(\Gamma+\bar{\Gamma})}{dq^2\,d\cos\theta_K\,d\cos\theta_L\,d\phi} = \frac{9}{32\pi}\Big[\tfrac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K$$
$$+\tfrac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_L - F_L\cos^2\theta_K\cos 2\theta_L$$
$$+S_3\sin^2\theta_K\sin^2\theta_L\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_L\cos\phi$$
$$+S_5\sin 2\theta_K\sin\theta_L\cos\phi + \tfrac{3}{4}A_{FB}\sin^2\theta_K\cos\theta_L$$
$$+S_7\sin 2\theta_K\sin\theta_L\sin\phi + S_8\sin 2\theta_K\sin 2\theta_L\sin\phi$$
$$+S_9\sin^2\theta_K\sin^2\theta_L\sin 2\phi\Big]$$



$B^0 \to K^*\mu^+\mu^-$ angular analysis

PRL 125(2020)01 1802

- Measure 8 angular observables in 8 q^2 bins
- Deviations at 1-2 sigma level observed in some observables
  → is it simply look-elsewhere effect?

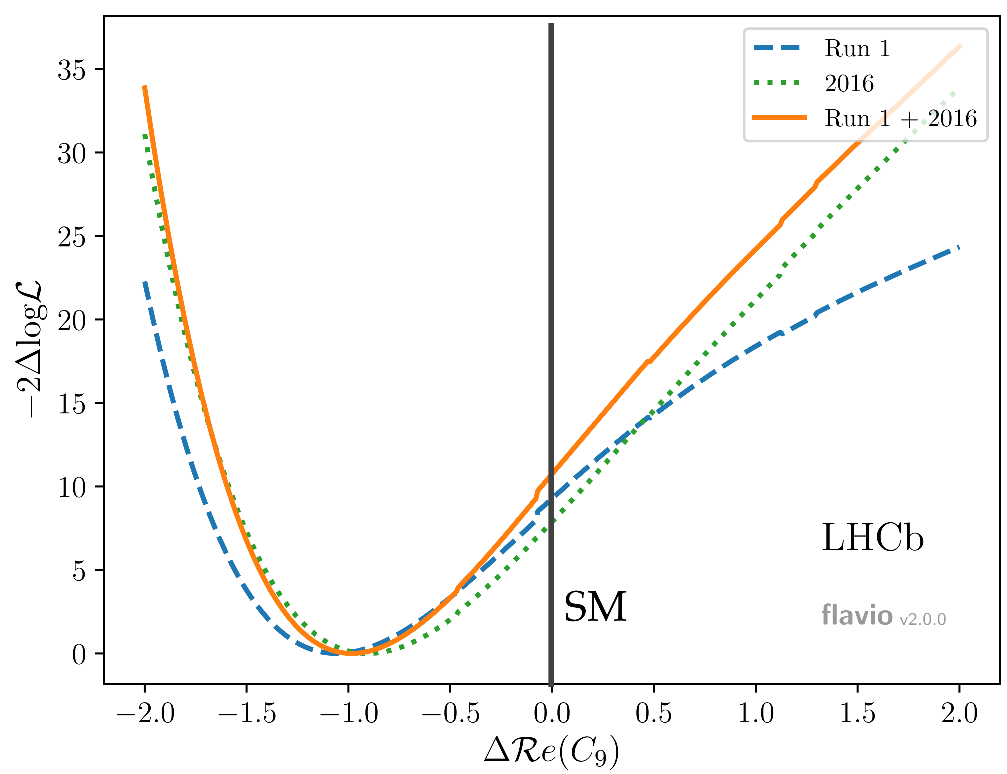


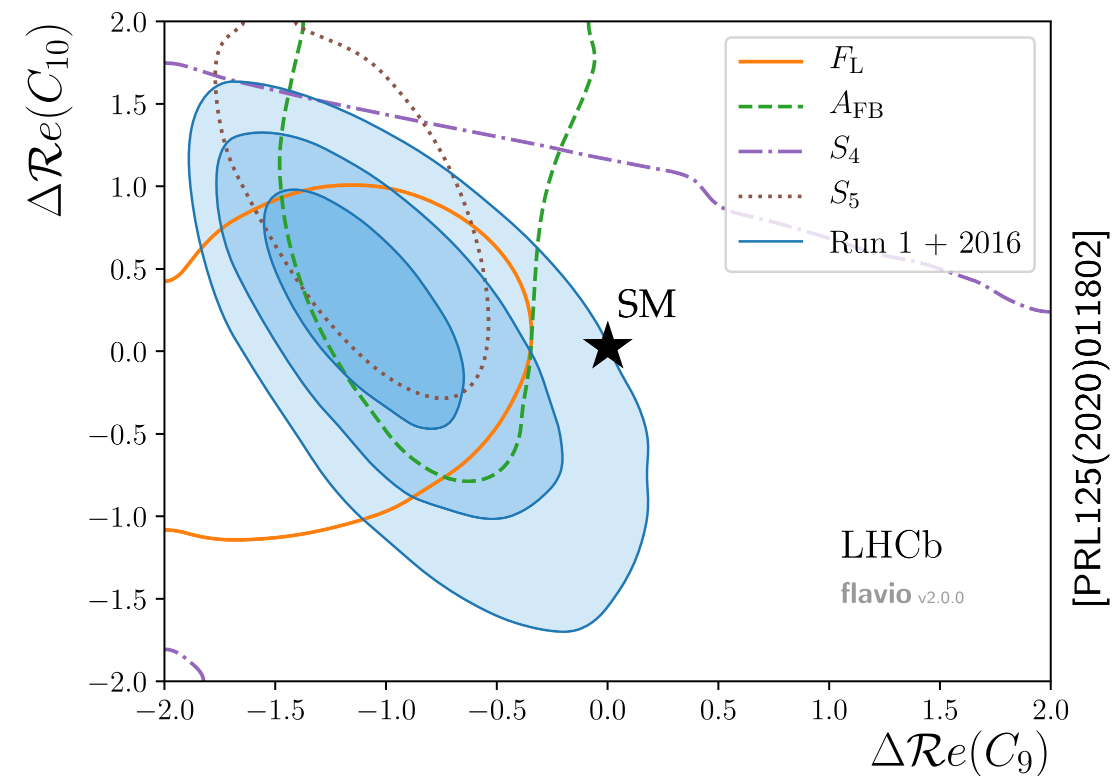
[PRL125(2020)011802]

$B^0 \to K^*\mu^+\mu^-$ angular analysis

PRL 125(2020)01 1802

- Global fit of Wilson coefficients seems to indicate a pattern
- Deviations are best explained by a shift in C_9
  - They agree between Run 1 and 2016 data
  - Different observables give a coherent picture





- Community has critical look on $c\bar{c}$ loop mimicking NP effect in C_9

Ciuchini et al NPPP 285–286 (2017) 45–49

Lepton universality tests

LU test in $b \to s\ell\ell$: μ vs e

- Can use $b \to s\ell\ell$ to test for LU-violating effects of New Physics
- Rare $b \to s\ell\ell$ with $\ell = \tau$ are not observed yet
- Can compare BR with $\ell = \mu$ and e : $$\mathcal{R}_{K^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)}\mu\mu)}{\mathcal{B}(B \to K^{(*)}ee)}$$
  - LU QCD uncertainties completely cancels in the ratio
  - Largest uncertainty remaining is 1% due to QED corrections (taken into account with PHOTOS, but with approximations)

Bordone, Isidori, Pattori EPJC(2016)76:440

- Previous tests at B-factories not very sensitive
- LHCb has much better sensitivity, but electrons challenging
  - Selection, bremsstrahlung, resolution, modelling

e^+e^- at LHCb: Selection

- **Electrons** at LHCb:
  - Being light, they are produced in a plethora of decay channels
  - **Trigger** on large $e^\pm/h^\pm$ energy deposit on calorimeters
  - **Electron ID** relies on calorimeter for suppression of π mis-ID
  - Large **combinatorial background**: machine-learning based classification using kinematics info and isolation
- Muons trigger and ID is easier
  - Selection more efficient by factor ~3

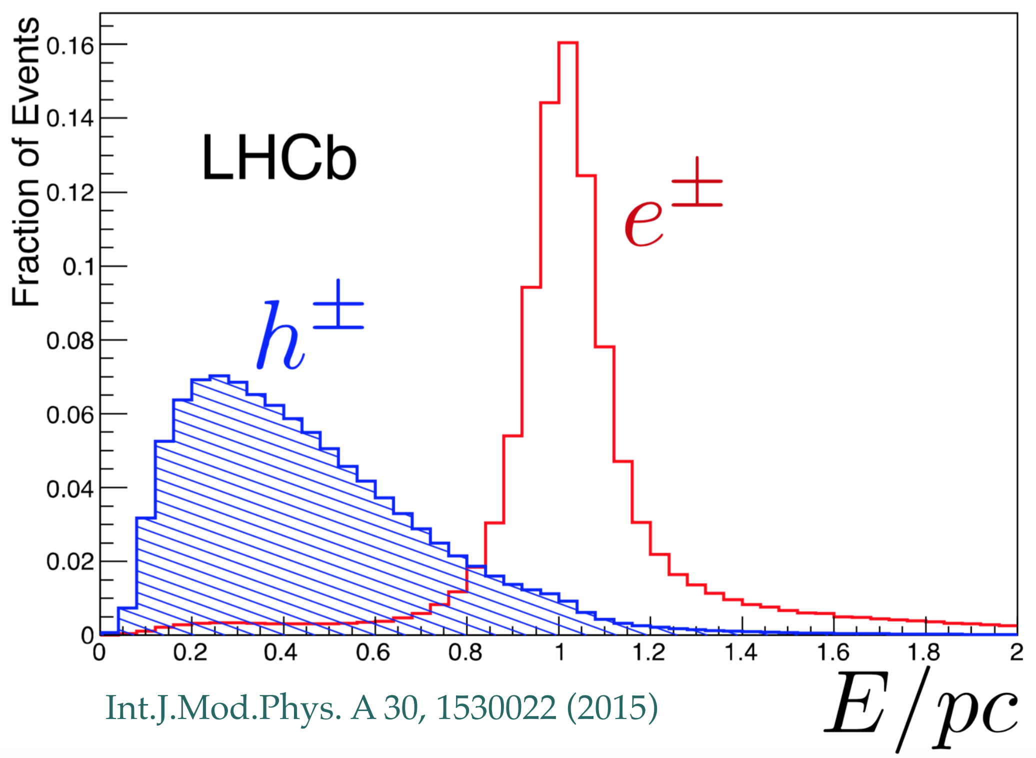
$$\frac{N\left(B^+ \to K^+\mu^+\mu^-\right)}{N\left(B^+ \to K^+e^+e^-\right)} \simeq 3$$

Phys. Rev. Lett. 122 (2019) 191801

Hardware trigger at LHCb:

- $p_T(\mu^\pm) > 1.5 - 1.8$ GeV
- $E_T(e^\pm) > 2.5 - 3.0$ GeV

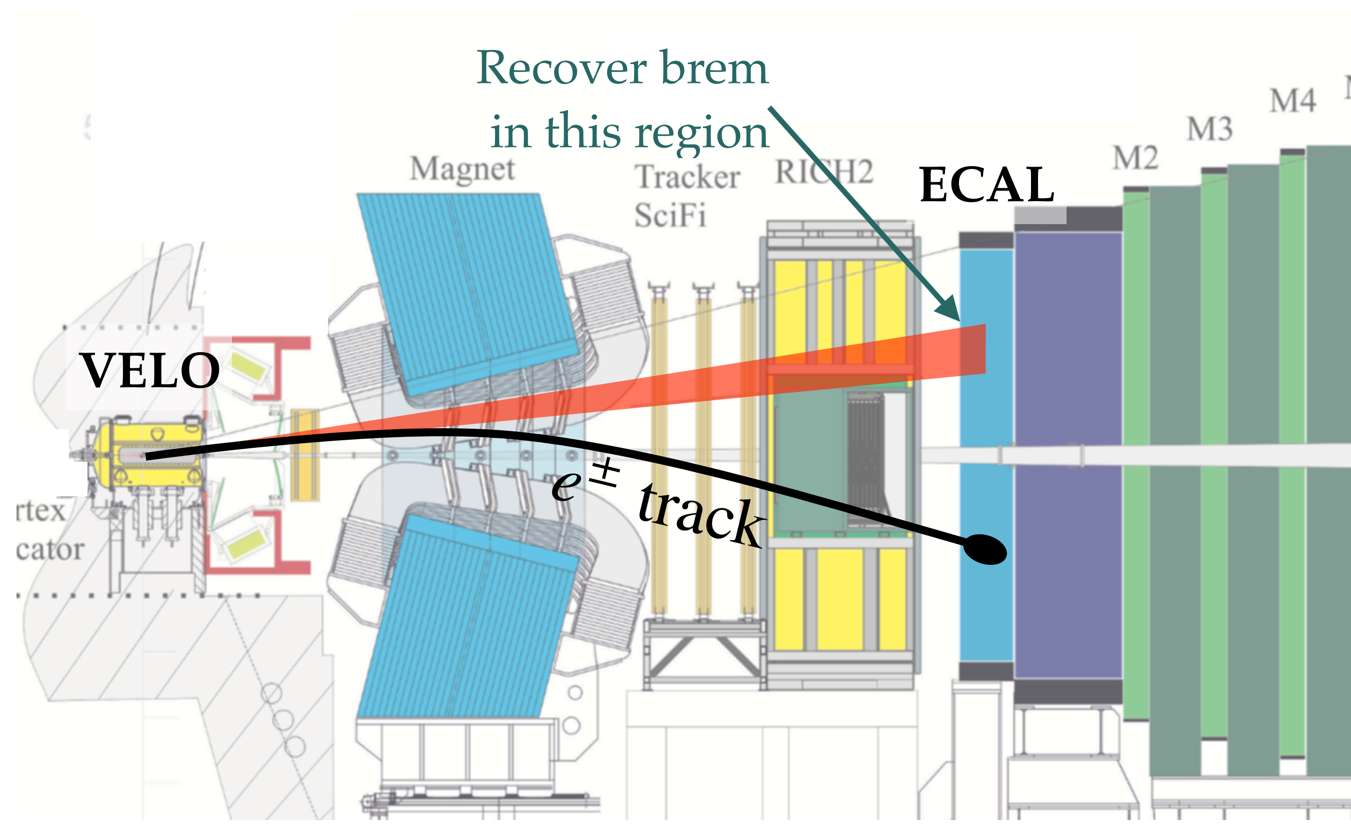
Electron ID at LHCb



Int.J.Mod.Phys. A 30, 1530022 (2015)

e^+e^- at LHCb: Bremsstrahlung

- Boosted B from LHC collision
  - Most electrons emit hard **bremsstrahlung** photon
  - If emitted **before the magnet it** affects the momentum measurement
- Brem-recovery algorithm searches for compatible deposits in the calorimeter LHCb, JHEP 08 (2017) 055
  - Recovery efficiency is limited (but well reproduced in simulation)
  - **ECAL resolution** is worse than spectrometer (1-2% vs 0.5%)



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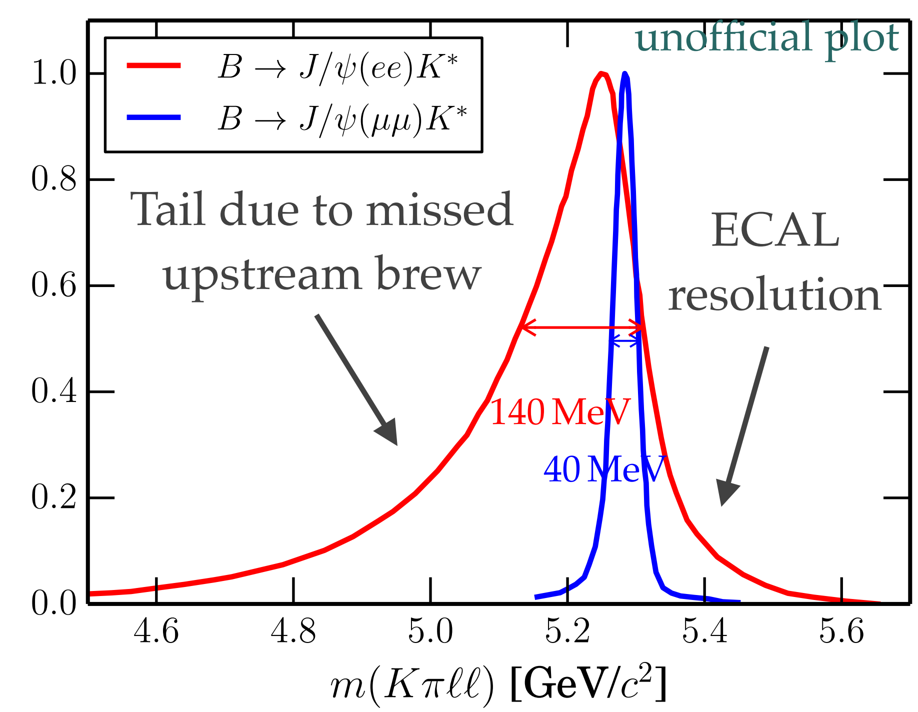
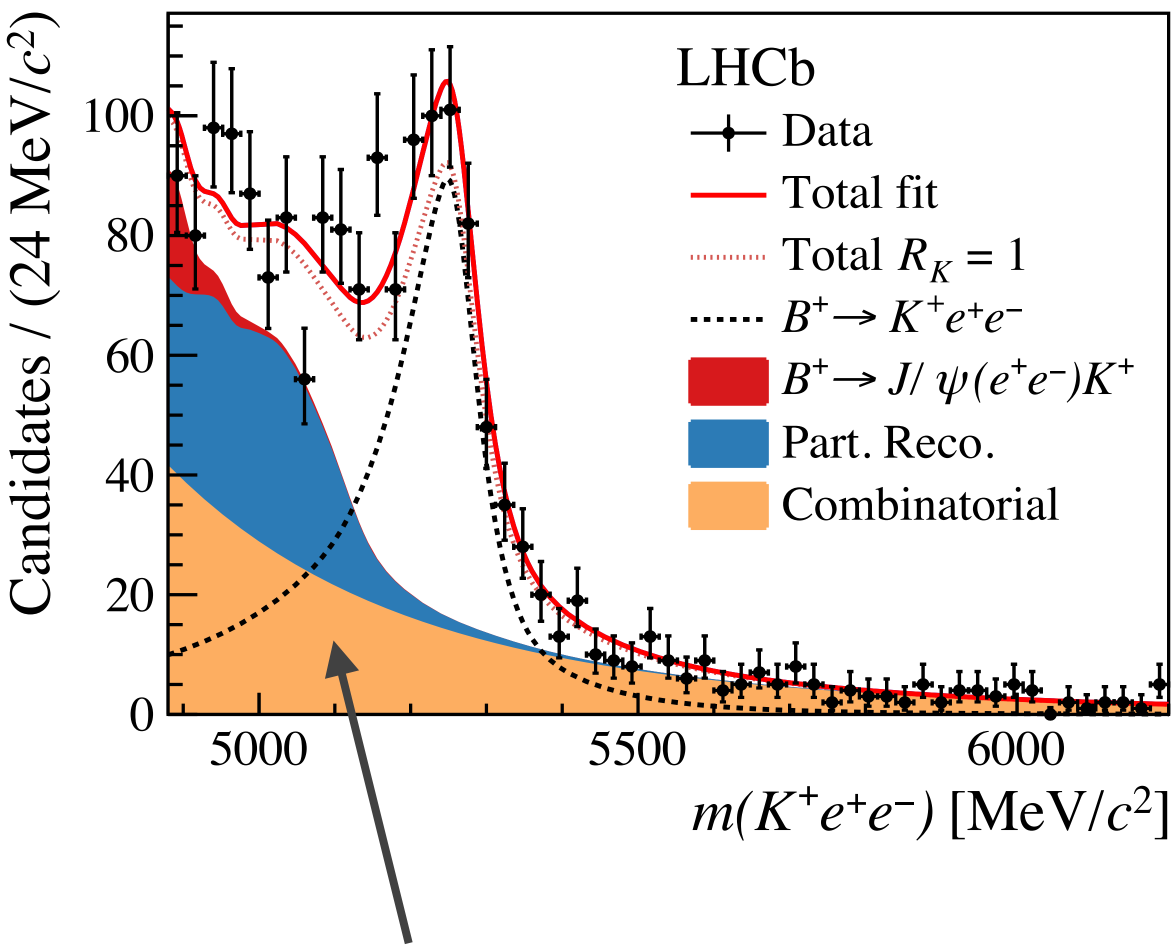
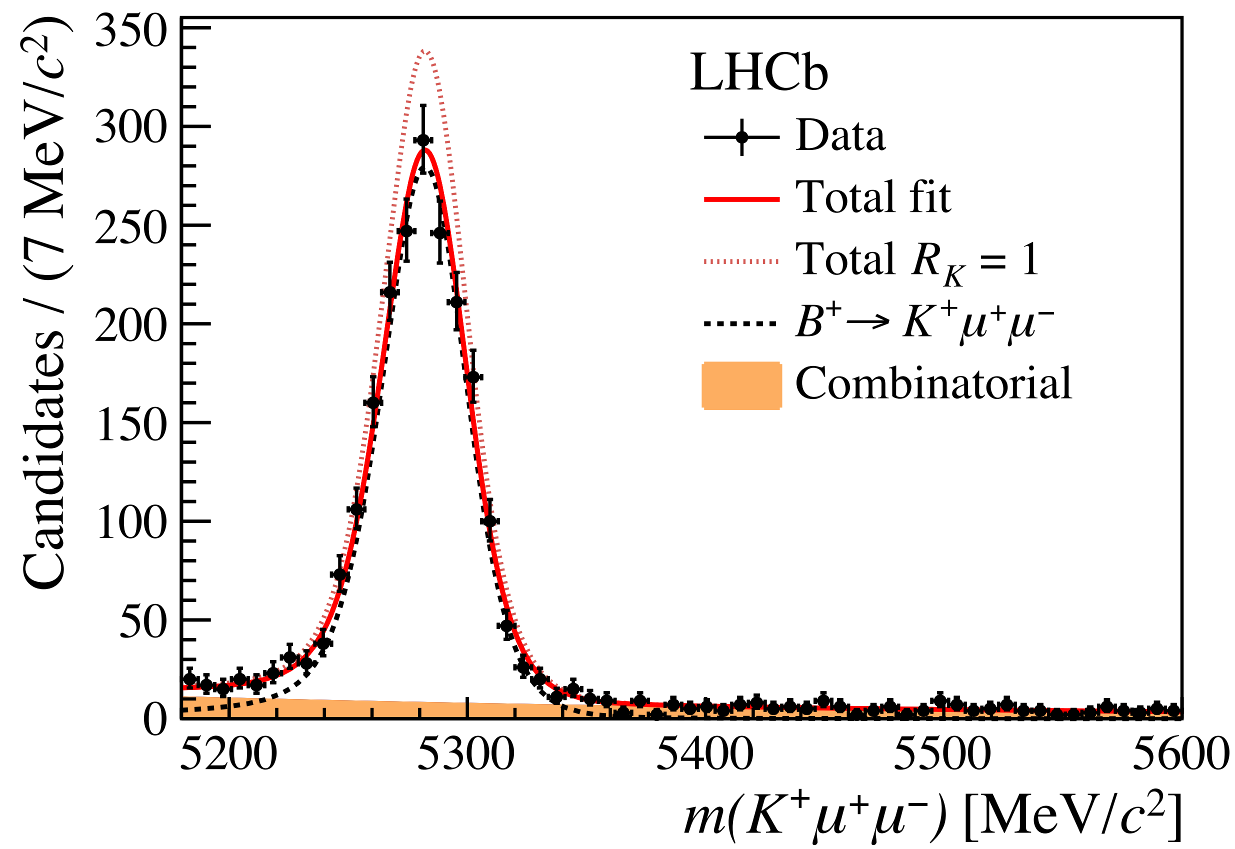


e^+e^- at LHCb: Resolution

Phys. Rev. Lett. 122 (2019) 191801





- Background with missing pion due to mass resolution
- Combinatorial background is larger (many electrons)
- Signal mass shape controlled with $J/\psi \to e^+e^-$ channel

e^+e^- at LHCb: Modelling

Phys. Rev. Lett. 122 (2019) 191801

- Use **double ratio:**

$$\mathcal{R}_K = \frac{\mathcal{B}(B^+ \to K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \to K^+ J/\psi\,(\mu^+ \mu^-))} \frac{\mathcal{B}(B^+ \to K^+ J/\psi\,(e^+ e^-))}{\mathcal{B}(B^+ \to K^+ e^+ e^-)} =$$

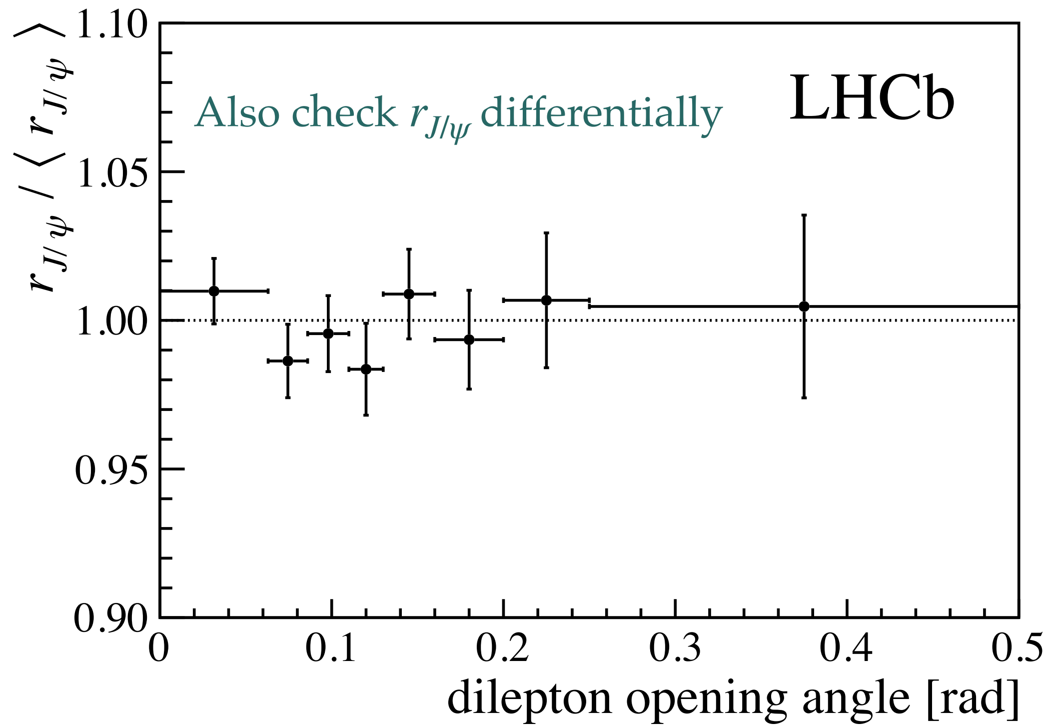
$$= \frac{N_{K^+ \mu^+ \mu^-}}{N_{K^+ J/\psi\,(\mu^+ \mu^-)}} \frac{N_{K^+ J/\psi\,(e^+ e^-)}}{N_{K^+ e^+ e^-}} \boxed{\frac{\epsilon_{K^+ J/\psi\,(\mu^+ \mu^-)}}{\epsilon_{K^+ \mu^+ \mu^-}}} \boxed{\frac{\epsilon_{K^+ e^+ e^-}}{\epsilon_{K^+ J/\psi\,(e^+ e^-)}}}$$

$\rightarrow$ cancel systematics

- **Crosschecks** universality of QCD in $c\bar{c}$ resonances

$$r_{J/\psi} = \frac{B\left(B^+ \to J/\psi\left(\to \mu^+\mu^-\right) K^+\right)}{B\left(B^+ \to J/\psi\left(\to e^+e^-\right) K^+\right)} = 1.014 \pm 0.035$$

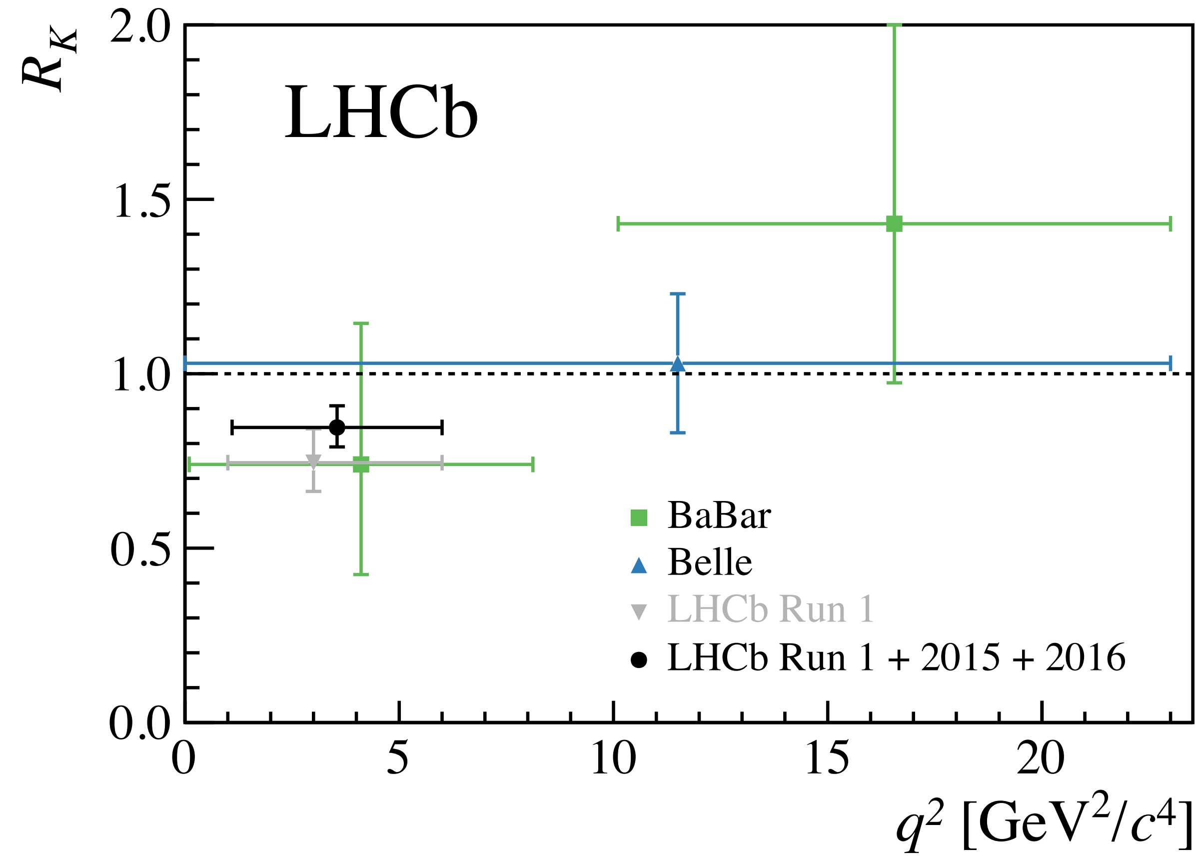
- Can also test that R_K measured at the $\psi(2S)$ is 1
$\rightarrow$ checked with 1.3% precision



R_K result

Phys. Rev. Lett. 122 (2019) 191801

- Measured with 2011-2016 dataset (5/fb at √s=7, 8 and 13 TeV)
- Measured central q^2 region [1-6] GeV²
- Yield of ~766 $B^+ \to K^+e^+e^-$ events (vs ~1943 in $B^+ \to K^+\mu^+\mu^-$) driving the total uncertainty:
  - 7% statistical error vs 2% systematic
- R_K is found to be lower than 1 by ~15%
  - Still compatible with the SM at **2.5σ level**



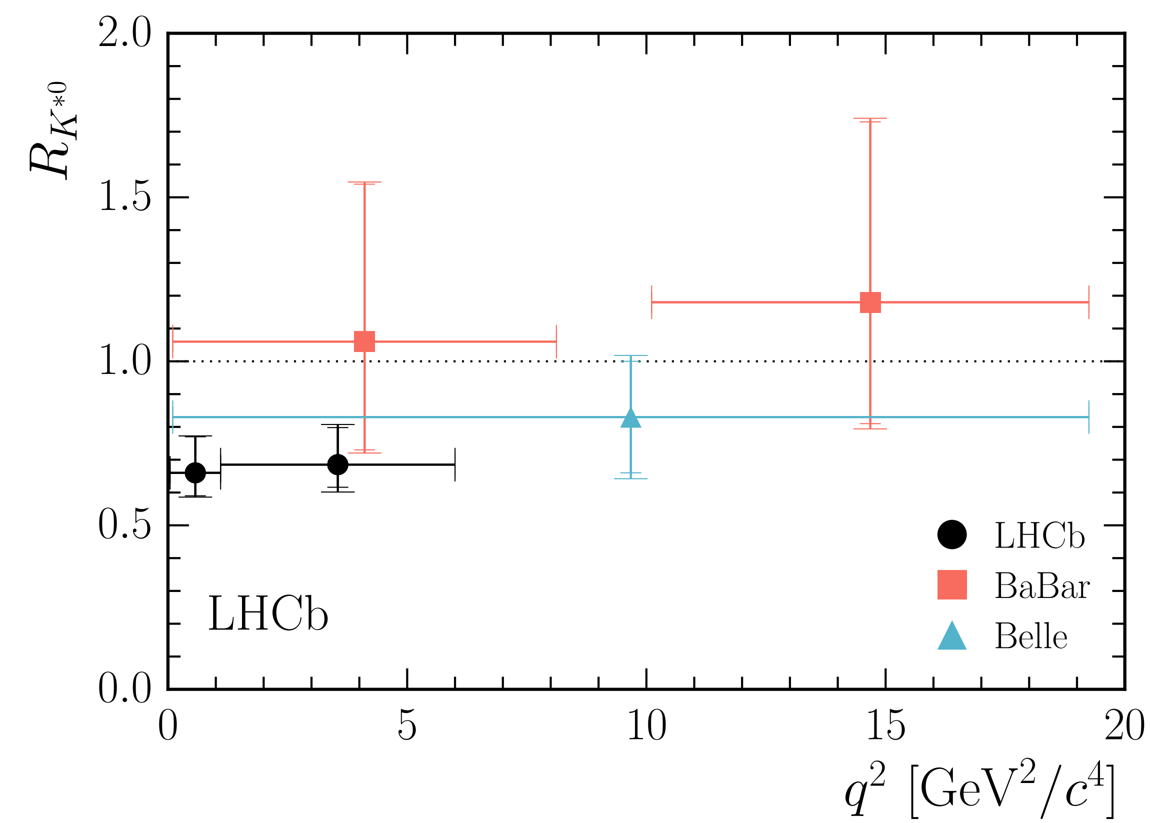
$$R_K = 0.846\,^{+0.060}_{-0.054}\,^{+0.016}_{-0.014}$$

R_{K^*} result

LHCb, JHEP 08 (2017) 055

$$R_{K^{*0}} = \begin{cases} 0.66 \, ^{+\,0.11}_{-\,0.07} \, (\text{stat}) \pm 0.03 \, (\text{syst}) & \text{for } 0.045 < q^2 < 1.1 \;\; \text{GeV}^2/c^4 \\ 0.69 \, ^{+\,0.11}_{-\,0.07} \, (\text{stat}) \pm 0.05 \, (\text{syst}) & \text{for } 1.1 \quad\; < q^2 < 6.0 \;\; \text{GeV}^2/c^4 \end{cases}$$

- Similar deviation was observed in R_{K^*} using Run 1 data
- Precision of ~17% in both bins, statistically dominated
- Upcoming Run 1 + Run 2 update expected to reduce uncertainty by factor ~2

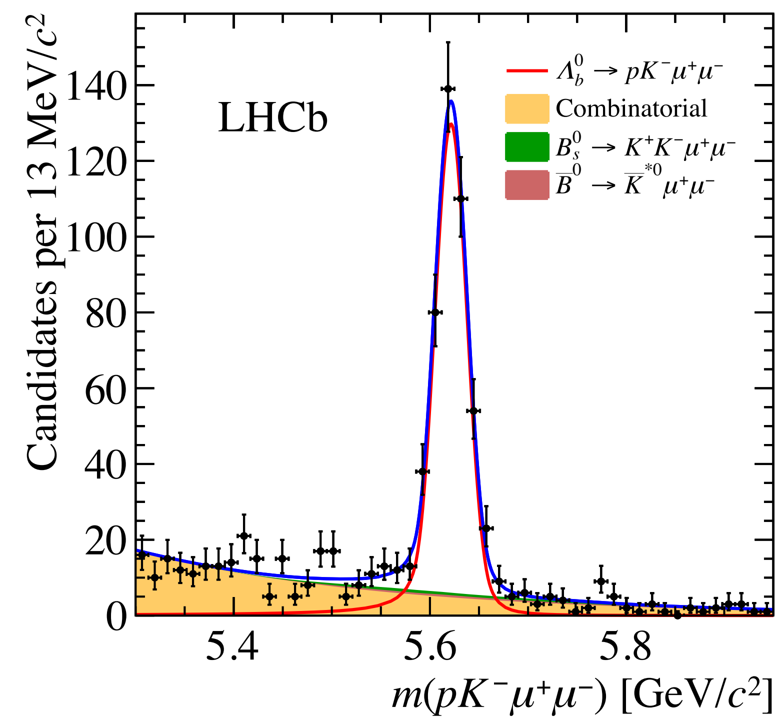


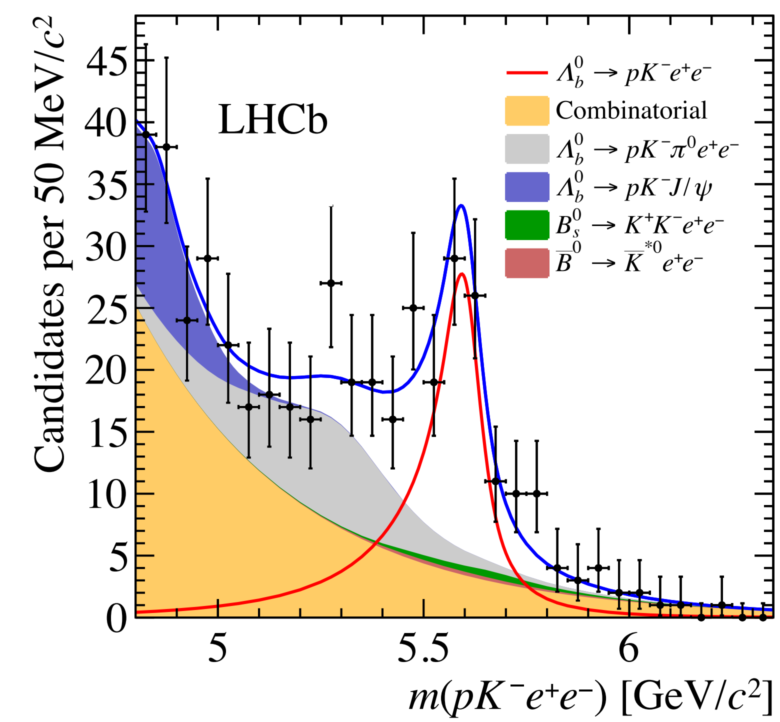
LU test in baryons

LHCb, JHEP 05 (2020) 040

- New test of LU in $\Lambda_b \to pK^-\ell^+\ell^-$
  - Using Run 1 + 2016 dataset (4.7/fb)
- Similar physics as R_K and
  - Different final state and selection
  - Different backgrounds and systematic uncertainties
- Crosscheck using $\Lambda_b \to pK^- J/\psi$
- Measured phase space region:
  - $m(pK^-) > 2.6$ GeV
  - $0.1 < q^2 < 6.0$ GeV^2

$$R_{pK}\big|_{0.1<q^2<6\,\mathrm{GeV}^2/c^4} = 0.86^{+0.14}_{-0.11} \pm 0.05$$





A coherent pattern?

- LU deviations (theoretically clean) are consistent with $b \to s\mu\mu$ BR and angular analyses if NP only in μ

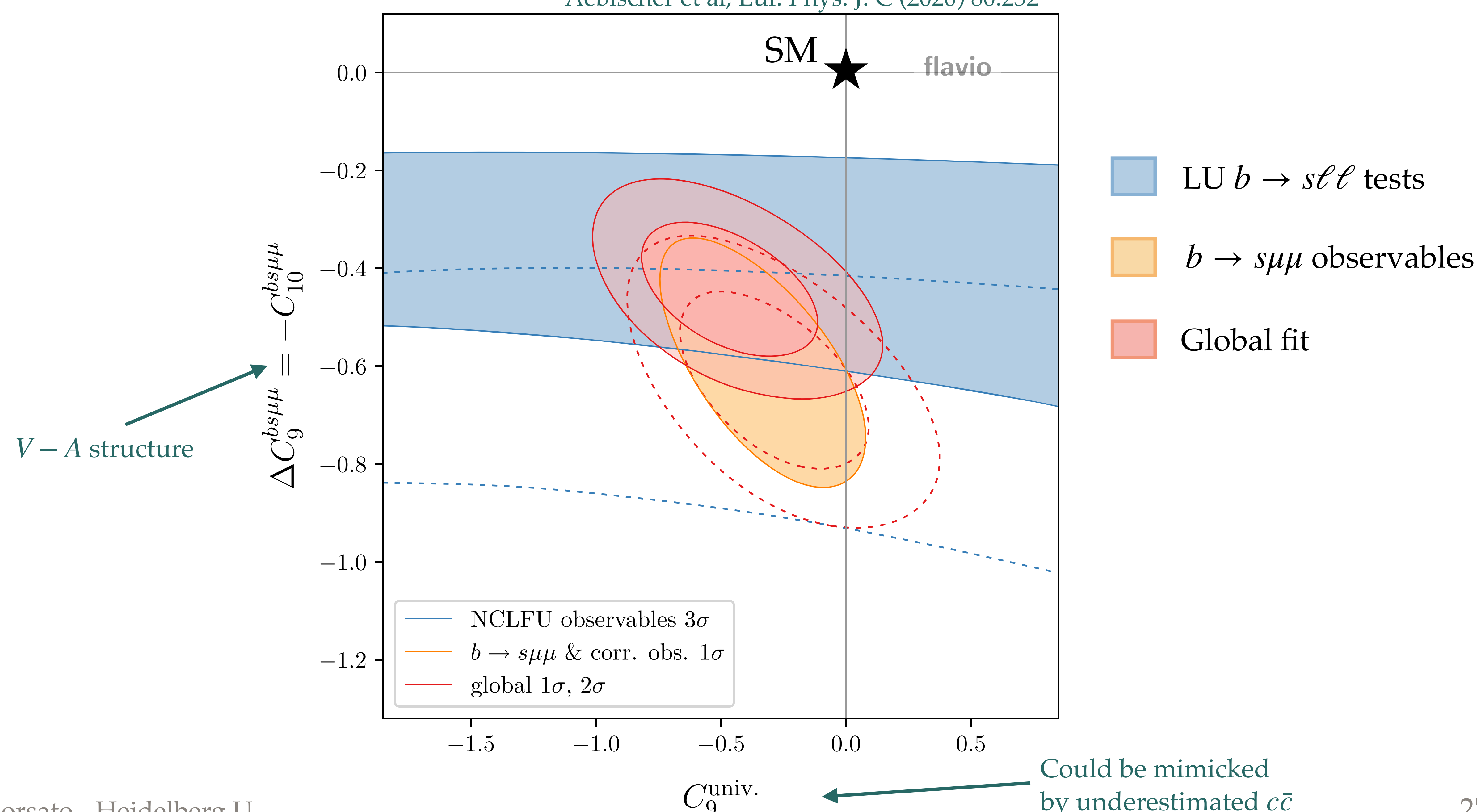
Coeff.	Best fit	1σ	2σ	Pull
$C_9^{bs\mu\mu}$	-0.97	$[-1.12, -0.81]$	$[-1.27, -0.65]$	5.9σ
$C_9'^{bs\mu\mu}$	$+0.14$	$[-0.03, +0.32]$	$[-0.20, +0.51]$	0.8σ
$C_{10}^{bs\mu\mu}$	$+0.75$	$[+0.62, +0.89]$	$[+0.48, +1.03]$	5.7σ
$C_{10}'^{bs\mu\mu}$	-0.24	$[-0.36, -0.12]$	$[-0.49, +0.00]$	2.0σ
$C_9^{bs\mu\mu} = C_{10}^{bs\mu\mu}$	$+0.20$	$[+0.06, +0.36]$	$[-0.09, +0.52]$	1.4σ
$C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$	-0.53	$[-0.61, -0.45]$	$[-0.69, -0.37]$	6.6σ
C_9^{bsee}	$+0.93$	$[+0.66, +1.17]$	$[+0.40, +1.42]$	3.5σ
$C_9'^{bsee}$	$+0.39$	$[+0.05, +0.65]$	$[-0.27, +0.95]$	1.2σ
C_{10}^{bsee}	-0.83	$[-1.05, -0.60]$	$[-1.28, -0.37]$	3.6σ
$C_{10}'^{bsee}$	-0.27	$[-0.57, -0.02]$	$[-0.84, +0.26]$	1.1σ
$C_9^{bsee} = C_{10}^{bsee}$	-1.49	$[-1.79, -1.18]$	$[-2.05, -0.79]$	3.2σ
$C_9^{bsee} = -C_{10}^{bsee}$	$+0.47$	$[+0.33, +0.59]$	$[+0.20, +0.73]$	3.5σ
$\left(C_S^{bs\mu\mu} = -C_P^{bs\mu\mu}\right) \times \text{GeV}$	-0.006	$[-0.009, -0.003]$	$[-0.014, -0.001]$	2.8σ
$\left(C_S'^{bs\mu\mu} = C_P'^{bs\mu\mu}\right) \times \text{GeV}$	-0.006	$[-0.009, -0.003]$	$[-0.014, -0.001]$	2.8σ

Aebischer et al, Eur. Phys. J. C (2020) 80:252

A coherent pattern?

- LU deviations (theoretically clean) are consistent with $b \to s\mu\mu$ BR and angular analyses if NP only in μ

Aebischer et al, Eur. Phys. J. C (2020) 80:252

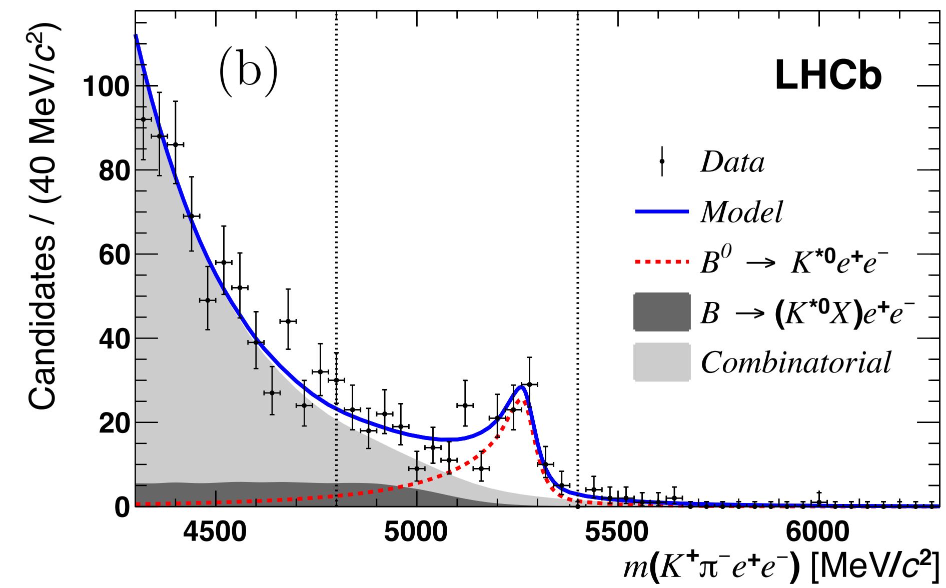


Prospects

$B^0 \to K^* e^+ e^-$ angular analysis

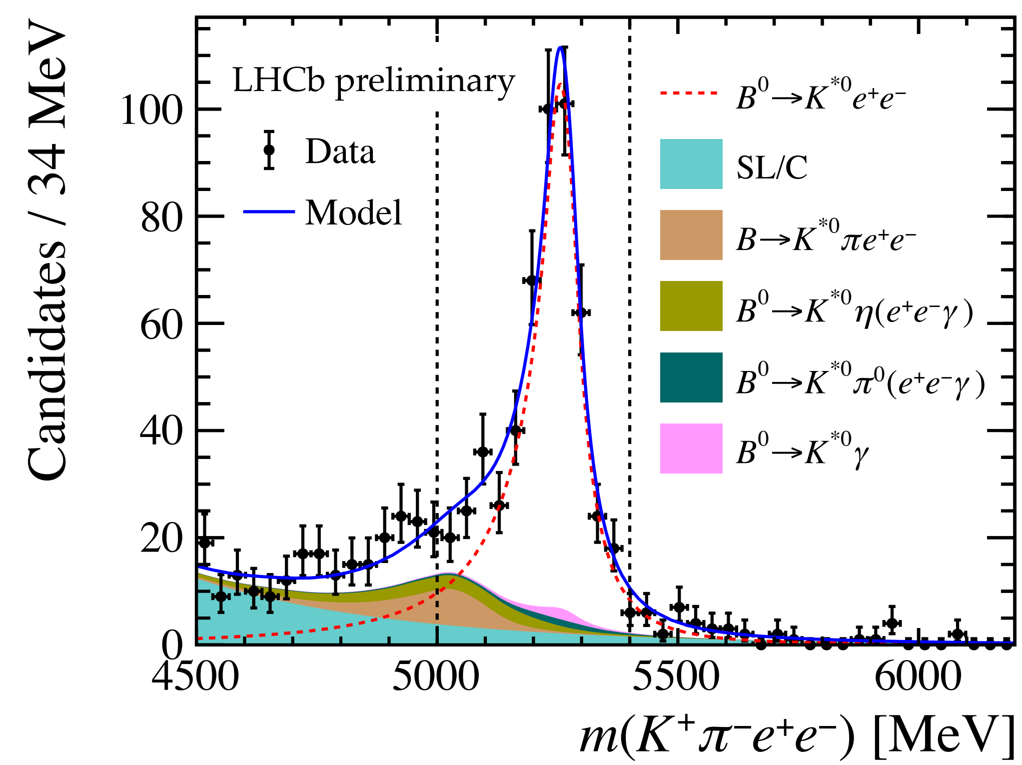
- Angular analysis at very low q^2
  - Aim is to measure $b \to s\gamma^*$
  - No sensitivity to Lepton Universality
  - Lower background made analysis possible already in Run 1
- New Run 2 analysis showcases the great improvements in the LHCb analyses of $b \to see$
- **Next step is to extend the analysis to higher q^2 values and compare to muons**

Run 1



LHCb, JHEP 04 (2015) 064

Run 1+2



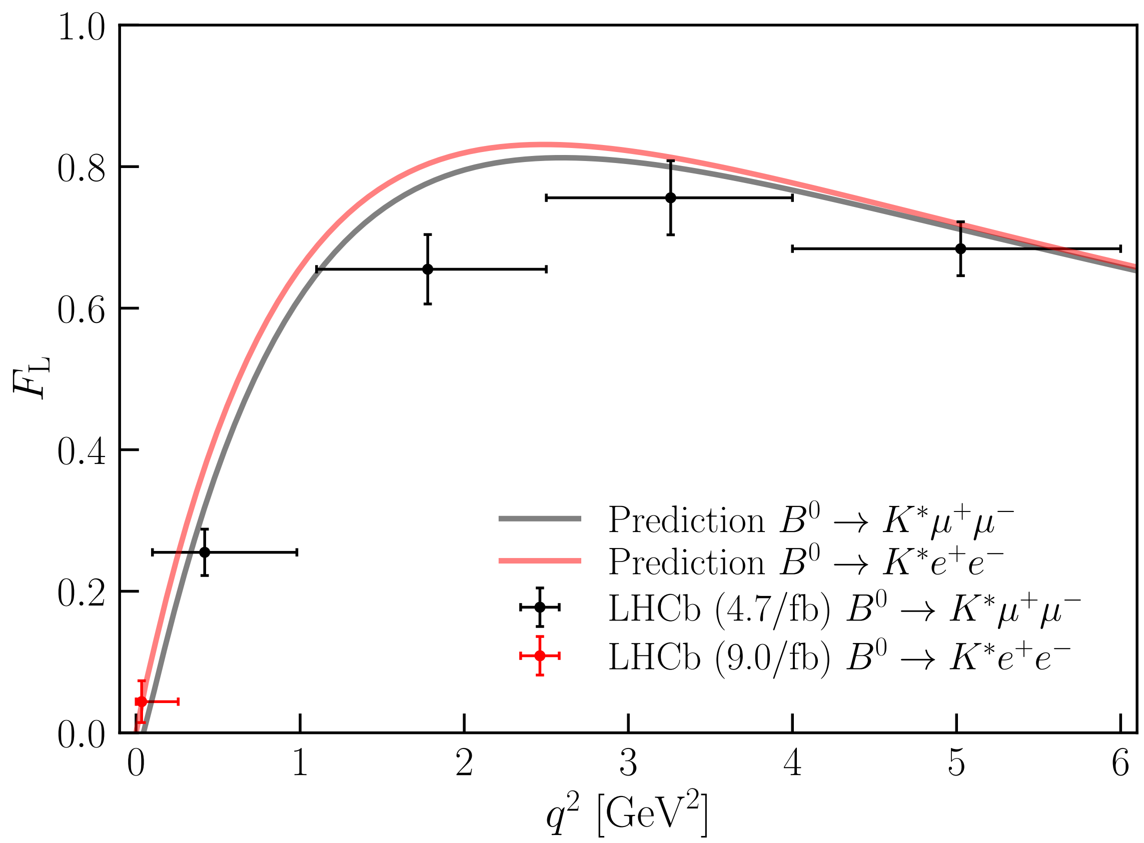
LHCb-PAPER-2020-020 (in preparation)

$B^0 \to K^{*} e^+ e^-$ angular analysis

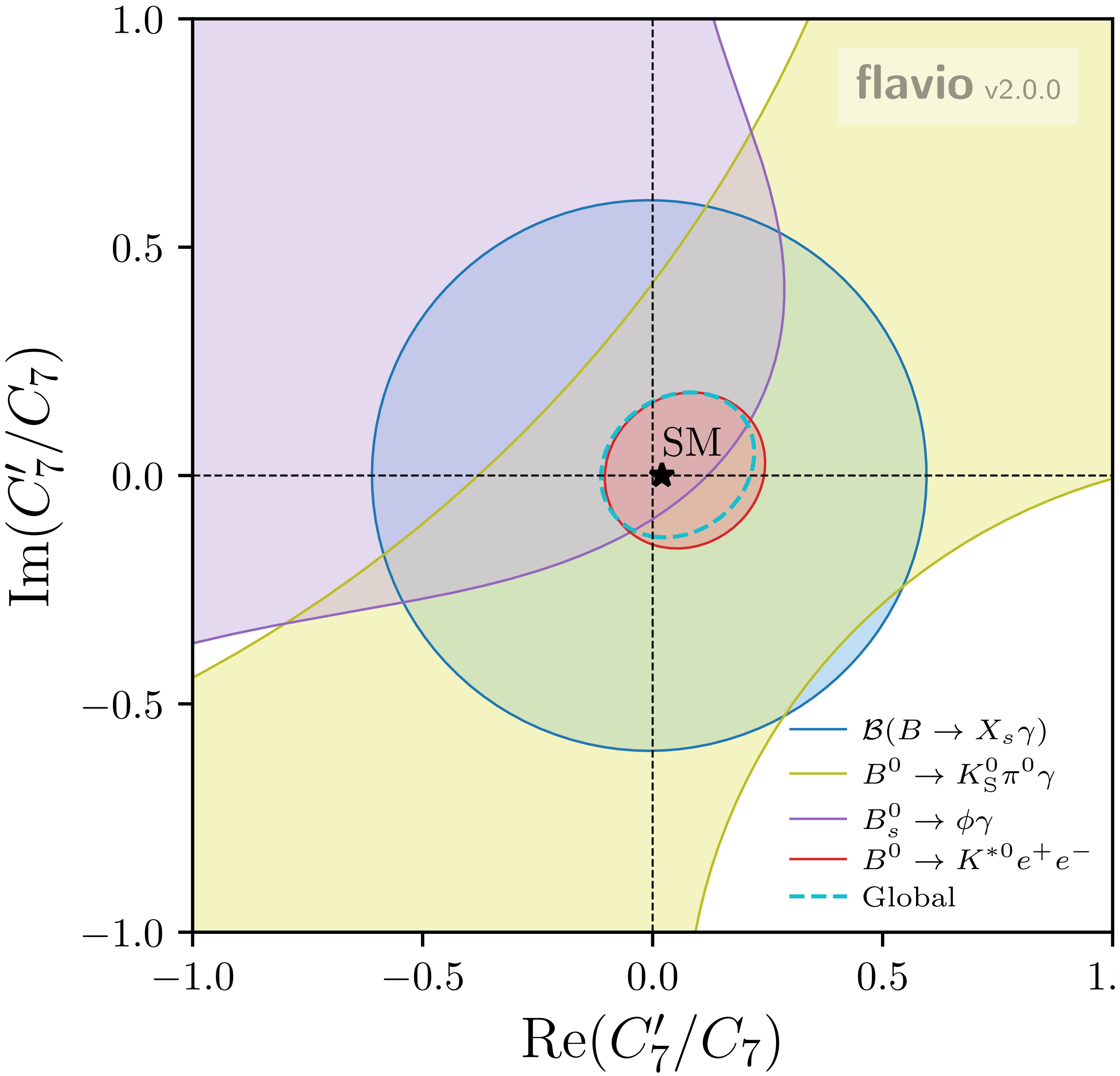
NEW

LHCb-PAPER-2020-020 (in preparation)

Measurement of $b \to see$ angular observables at very low q^2 (**red point**)



Most precise measurement (**red area**) of $b \to s\gamma$ photon polarisation



Upcoming Run 2 analyses

Prospects for muons

- Updates with full Run 2:
  - $B_{(s)} \to \mu^+\mu^-$
  - $B^0 \to K^*\mu^+\mu^-$
  - $B_s \to \phi\mu^+\mu^-$
- New analyses:
  - $B^+ \to K^{*+}\mu^+\mu^-$
  - Search for $B \to K^*\tau^+\tau^-$

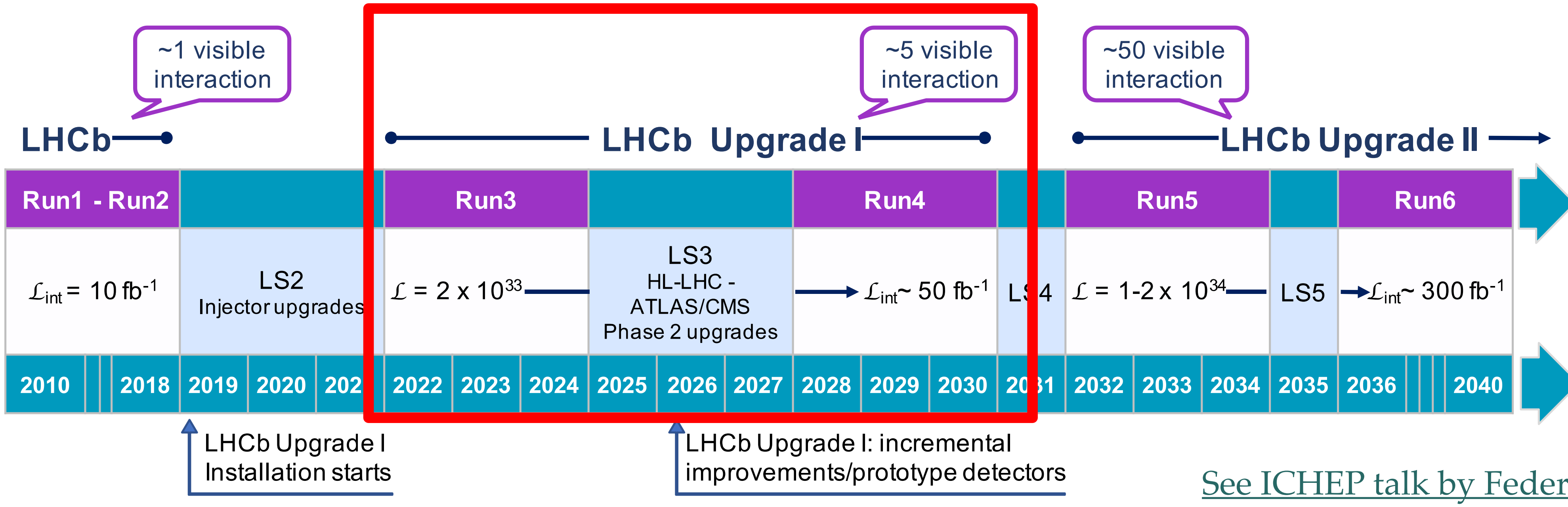
Prospects for LU tests

R_X precision	9fb^{-1}
R_K	0.043
$R_{K^{*0}}$	0.052
R_ϕ	0.130
R_{pK}	0.105
R_π	0.302

CERN-LHCC-2018-027

- Also several LFV searches ($e^+\mu^-$, $\mu^+\tau^-$)

LHCb upgrade

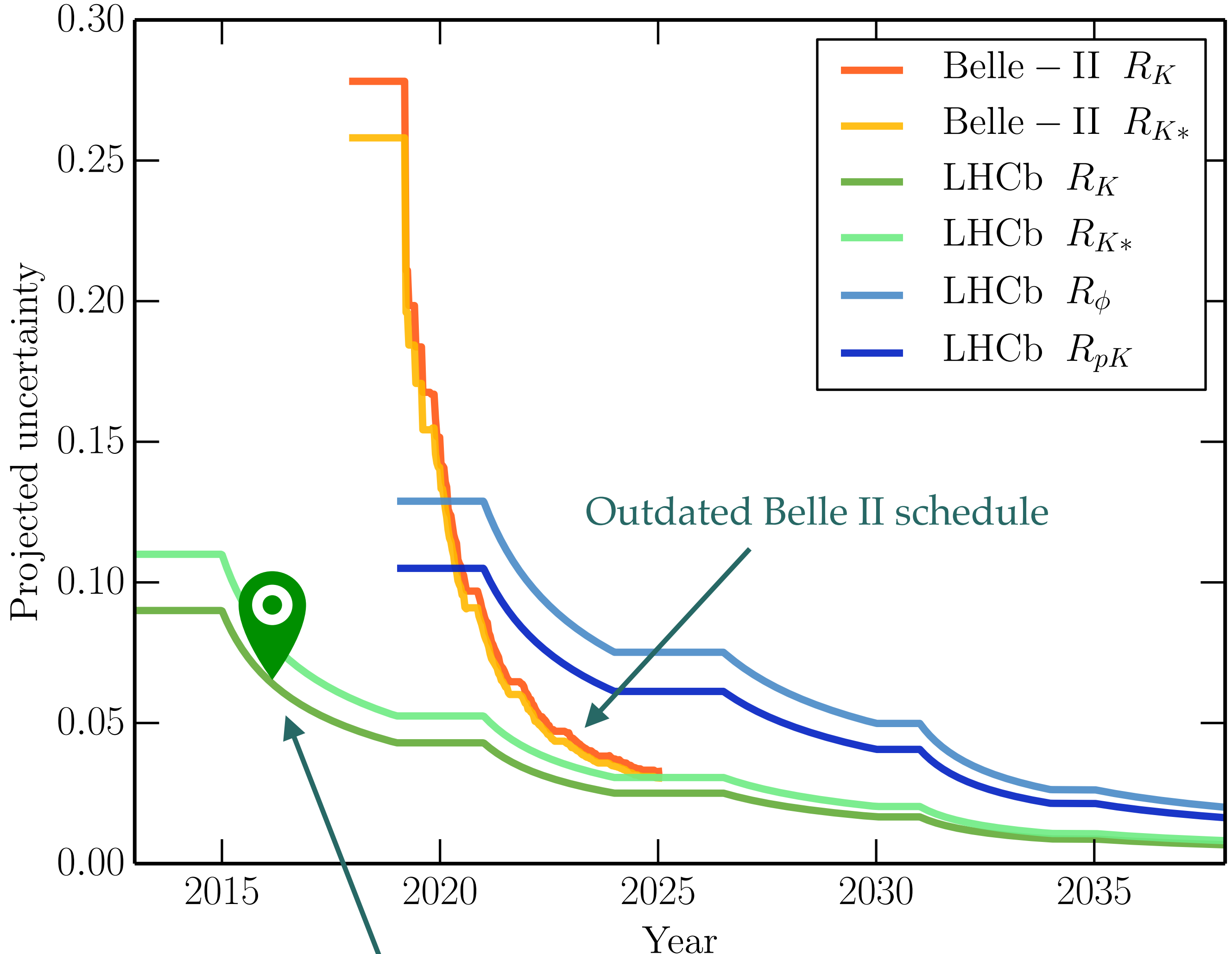


See ICHEP talk by Federico

- Preparing upgrade for LHC Run 3 and 4
  - Higher luminosity → collect 50/fb by the end of Run 4
  - Upgrade to maintain performance and improve trigger capabilities
- Upgraded LHCb detector:
  - More precise vertexing and tracking systems
  - Completely new readout system: throughput of 32 Tbps
  - Full software trigger on 500 modern GPUs

Prospects for LU tests precision

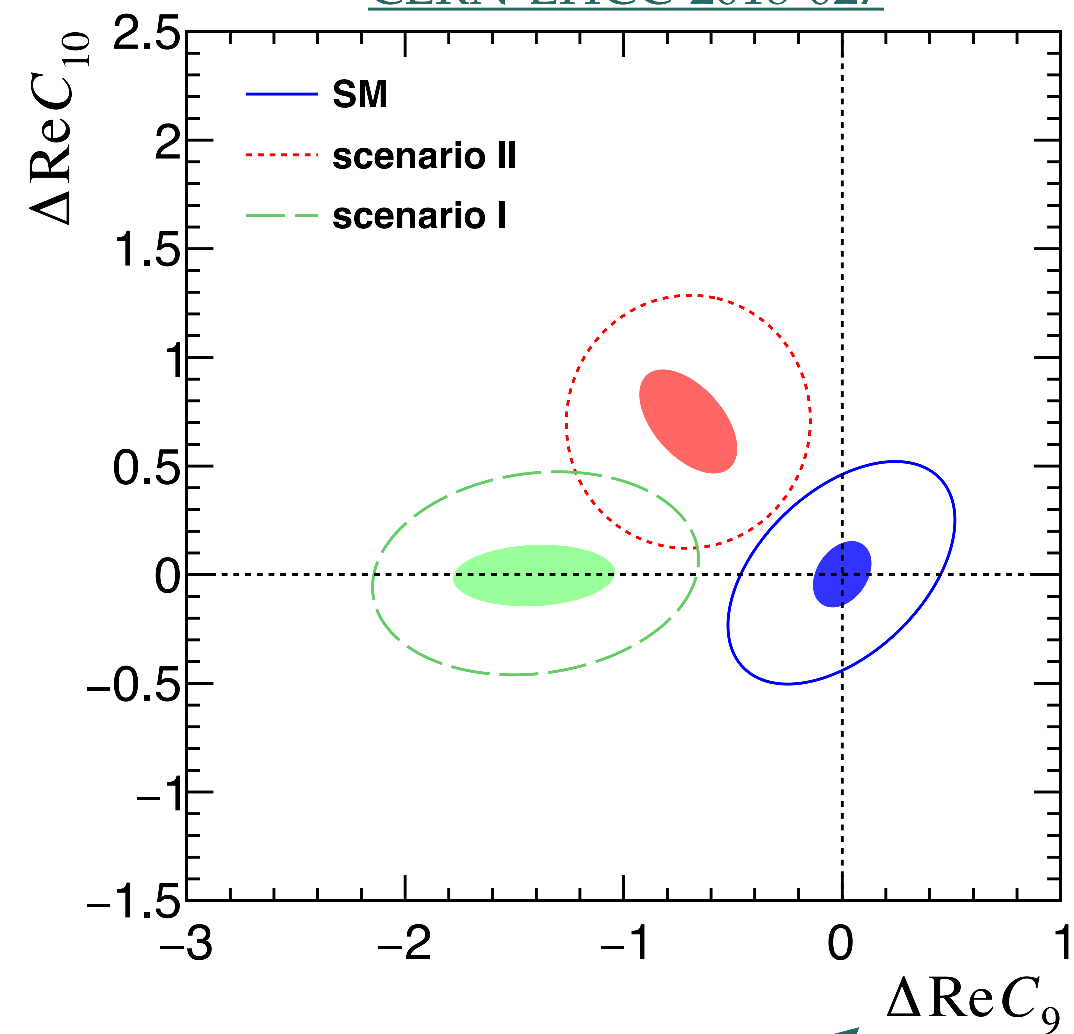
Bifani et al, J.Phys.G 46 (2019) 2, 023001



Outdated Belle II schedule

R_K with 7% precision
using data up to 2016

CERN-LHCC-2018-027



Δ between e
and μ modes

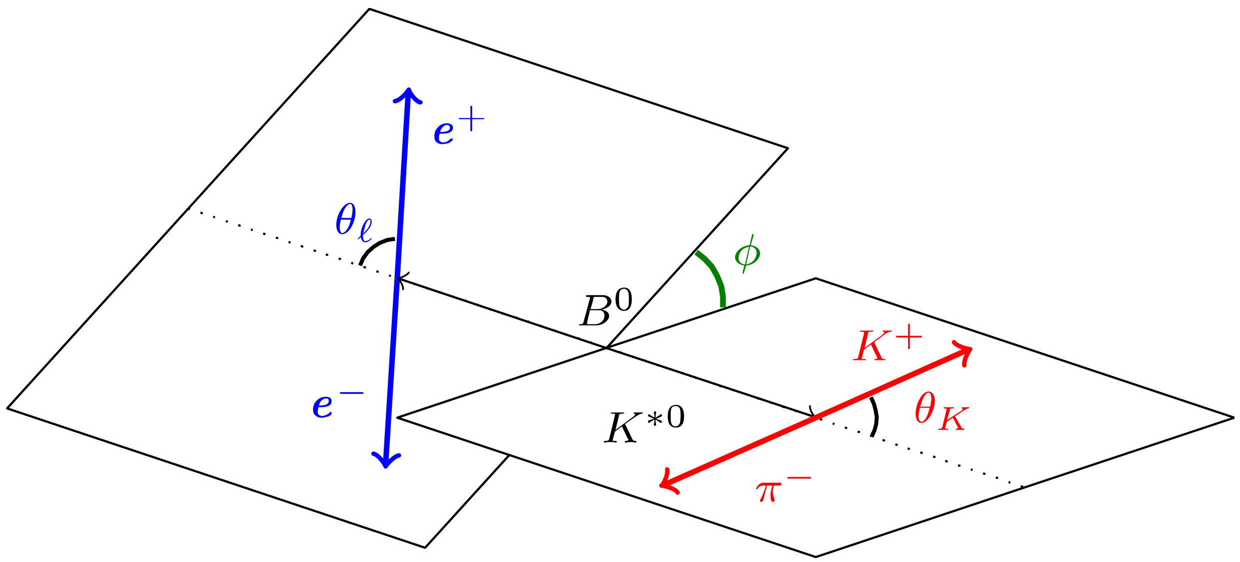
Summary

- Anomalies in the $b \to s\ell\ell$ sector are still interesting
  - Are we seeing a coherent pattern of anomalies?
- More data needed to solve the puzzle
  - Upcoming analyses of Run 2 data (on tape)
  - Upcoming LHCb upgrade (starting data-taking in 2021)
  - Other experiments: Belle II, CMS, ATLAS
- Stay tuned for new results

BACKUP

$B^0 \to K^* e^+ e^-$: Angular analysis

LHCb-PAPER-2020-020 (in preparation)



- Folding ϕ angle to simplify the 3D angular expression:

$$\tilde{\phi} \equiv \begin{cases} \phi \text{ if } \phi \geq 0 \\ \phi + \pi \text{ if } \phi < 0 \end{cases}$$

$$\frac{1}{\mathrm{d}(\Gamma + \bar{\Gamma})/\mathrm{d}q^2} \frac{\mathrm{d}^4(\Gamma + \bar{\Gamma})}{\mathrm{d}q^2\, \mathrm{d}\cos\theta_\ell\, \mathrm{d}\cos\theta_K\, \mathrm{d}\tilde{\phi}} = \frac{9}{16\pi} \Big[\tfrac{3}{4}(1 - F_\mathrm{L}) \sin^2\theta_K + F_\mathrm{L} \cos^2\theta_K$$
$$+ \tfrac{1}{4}(1 - F_\mathrm{L}) \sin^2\theta_K \cos 2\theta_\ell - F_\mathrm{L} \cos^2\theta_K \cos 2\theta_\ell$$
$$+ (1 - F_\mathrm{L}) A_T^{Re} \sin^2\theta_K \cos\theta_\ell$$
$$+ \tfrac{1}{2}(1 - F_\mathrm{L}) A_T^{(2)} \sin^2\theta_K \sin^2\theta_\ell \cos 2\tilde{\phi}$$
$$+ \tfrac{1}{2}(1 - F_\mathrm{L}) A_T^{Im} \sin^2\theta_K \sin^2\theta_\ell \sin 2\tilde{\phi} \Big].$$

$B^0 \to K^*\gamma$ photon polarisation:

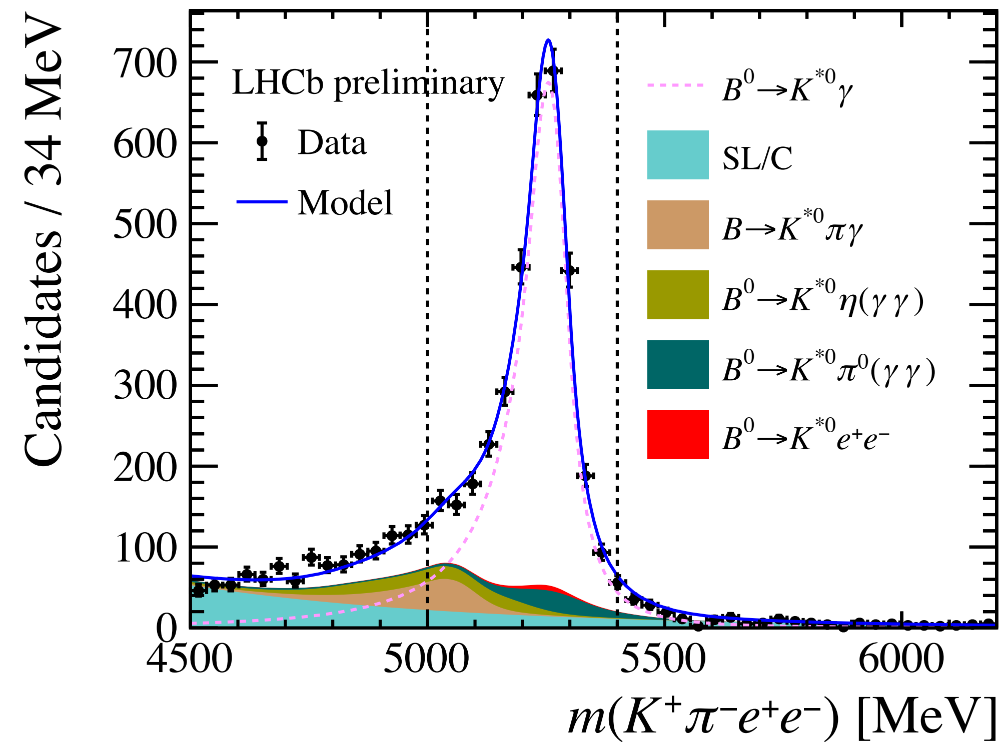
$$A_{\mathrm{R(L)}} \equiv |A_{\mathrm{R(L)}}| e^{i\phi_{\mathrm{R(L)}}}, \quad \tan\chi \equiv \left| A_\mathrm{R}/A_\mathrm{L} \right|$$

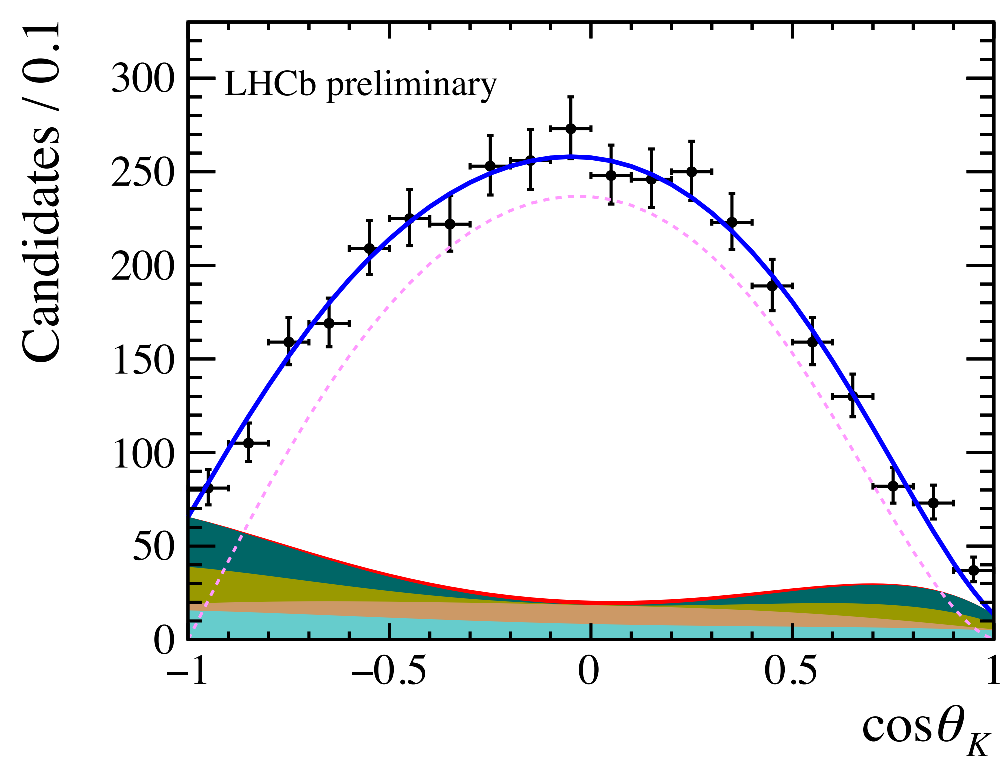
$$A_\mathrm{T}^{(2)} \simeq \sin(2\chi)\cos(\phi_\mathrm{L} - \phi_\mathrm{R}),$$
$$A_\mathrm{T}^{\mathrm{Im}} \simeq \sin(2\chi)\sin(\phi_\mathrm{L} - \phi_\mathrm{R}),$$

$B^0 \to K^{*}e^+e^-$: Control channel

LHCb-PAPER-2020-020 (in preparation)

- $B^0 \to K^{*}\gamma$ has much larger BR
  - Same final state as $B^0 \to K^{*}e^+e^-$ when γ converts to e^+e^- in the material
  - Can be well separated with material veto and cut on $m(e^+e^-) > 10$ MeV
- Use $B^0 \to K^{*}\gamma$ as control for $B^0 \to K^{*}e^+e^-$
  - Very similar signal shape and background composition to signal
  - Fit $m(K^+\pi^-e^+e^-)$ distribution to validate signal fit (found 2950 $B^0 \to K^{*}\gamma$ candidates)
  - Fitted F_L to $\cos\theta_K$ found to be compatible with 0 with sub-percent precision
    $\to$ due to real γ, longitudinal polarisation fraction F_L is expected to be zero

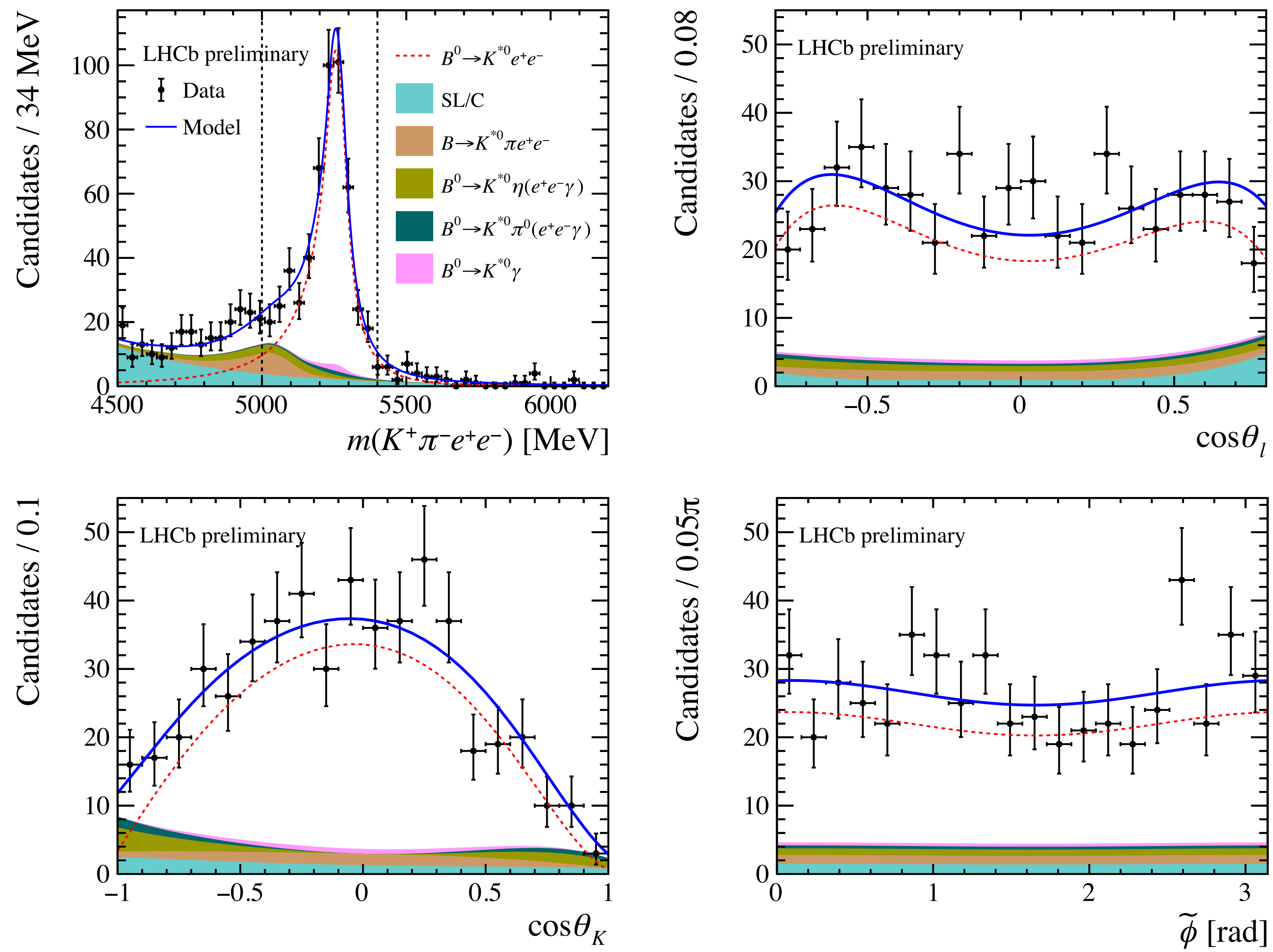




$B^0 \to K^{*}e^{+}e^{-}$: Angular fit

LHCb-PAPER-2020-020 (in preparation)

- Fit to B mass and angles
  - In reduced mass region
  - Semilept+combinatorial (SL/C) modelled using $B \to K^{*}\mu^{\pm}e^{\mp}$ data candidates
  - Other backgrounds from simulation
  - Fit procedure thoroughly tested with pseudo-experiments



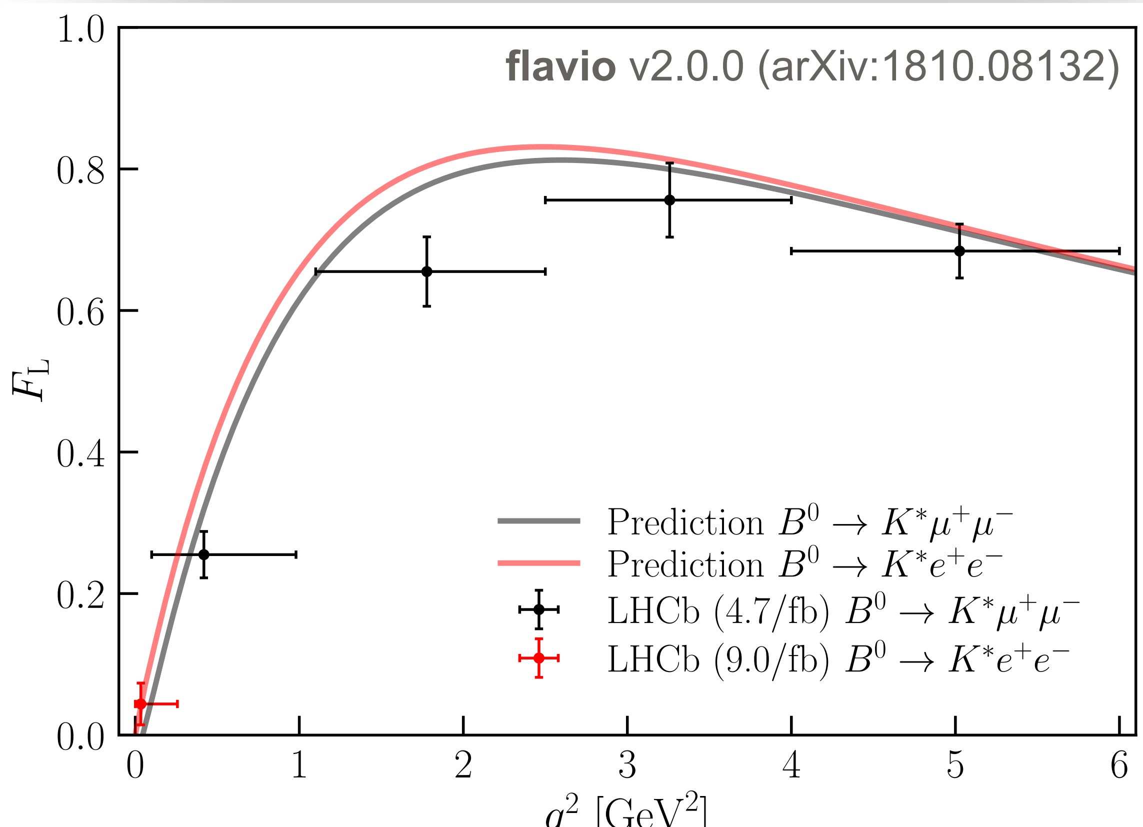
$B^0 \to K^* e^+ e^-$: Results

LHCb-PAPER-2020-020 (in preparation)

$(28\ \text{MeV})^2 < q^2 < 0.257\ \text{GeV}^2$

PRELIMINARY

$$F_L = 0.044 \pm 0.026 \pm 0.014$$
$$A_T^{Re} = -0.064 \pm 0.077 \pm 0.015$$
$$A_T^{(2)} = +0.106 \pm 0.103^{+0.016}_{-0.017}$$
$$A_T^{Im} = +0.015 \pm 0.102 \pm 0.012$$



LHCb, PRL 125(2020)011802
LHCb-PAPER-2020-020 (in preparation)

- Main systematics from signal acceptance and angular background modelling
- Statistical error still dominates
- Measurements of F_L and $A_T^{Re} = \frac{3}{4} A_{FB}(1 - F_L)$ are also interesting in the context of $B^0 \to K^* \mu^+ \mu^-$ angular analysis anomalies (see David's talk)

LHCb, PRL 125(2020)011802

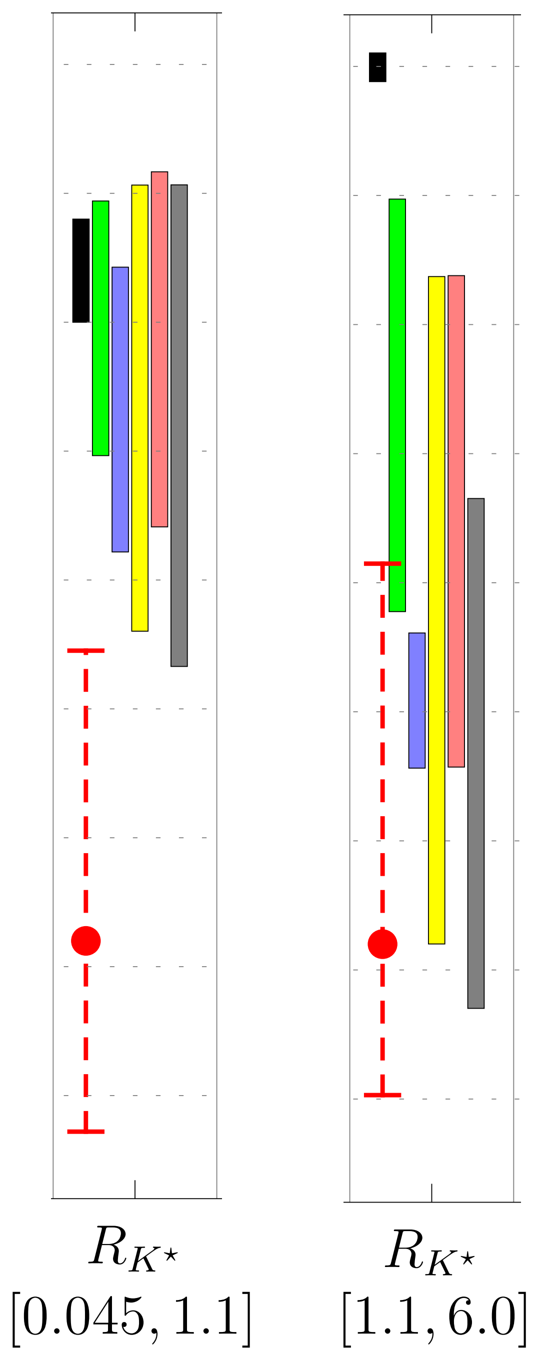
- The analysis prepares the ground for lepton universality tests in the angles
- $A_T^{(2)}$ and A_T^{Im} are sensitive to C_7'

next slide

The first R_{K^*} bin

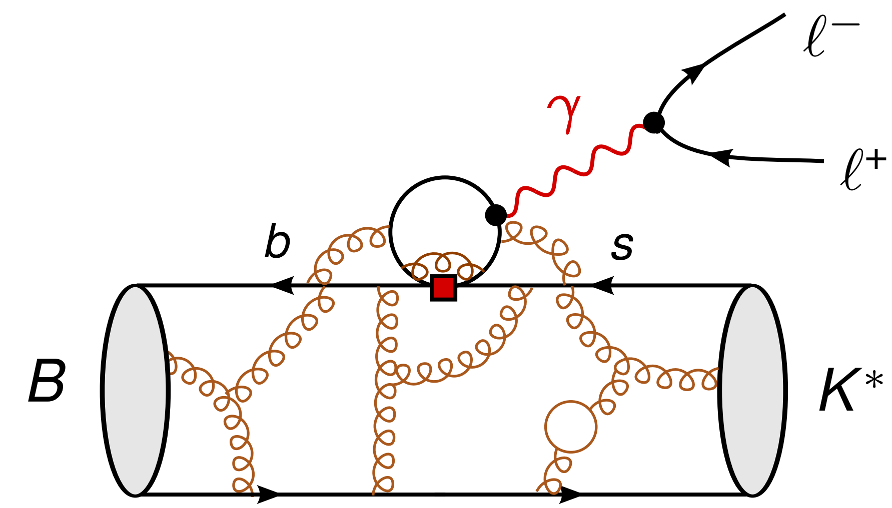
- Favoured region of q^2 is [1.1-6]
  - Far from photon pole and from J/ψ tail
  - Sensitive to New Physics in C_9 and C_{10}
- Thanks to photon pole the [$4m_\mu^2$ - 1.1] bin has enough statistics for a measurement
  - Dominated by dipole operator O_7
    - C_7 already very constrained by $b \to s\gamma$
    - Deviation pointing to underestimated systematic?
  - SM LU is broken close to threshold
  - LUV breaks cancellation of form factors

B.Capdevilla et al arXiv:1704.05340



Anomalies in $b \to s\mu\mu$ (?)

- Community has critical look on *cc* loop mimicking NP effect in C_9 (vector current)
  Ciuchini et al NPPP 285–286 (2017) 45–49
- Possible **experimental handles**:
  - NP in C9 would give helicity and q^2 independent effect while hadronic effects **could** be helicity and q^2 dependent
    W.Altmannshofer et al Eur.Phys.J. C77 (2017) no.6, 377
  - Perform full angular analysis of $B \to K^*\mu\mu$ including *cc* resonances and measure interference phases
    Blake et al., arXiv:1709.03921



Global fit as a function of q^2